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Developing a Water Management Plan: Exploring Water Conservation Strategies on the Illinois Wesleyan Campus

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Developing a Water Management Plan:

Exploring Water Conservation Strategies on the Illinois Wesleyan Campus

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Abstract

The primary purpose of this research was to collect the information necessary to one day develop an environmentally sound and economically feasible water conservation management plan for the Illinois Wesleyan University campus. Freshwater resources are steadily being depleted due to pollution and climate change, while demand for potable water continues to rise alongside an exponentially growing global population. Due to this reason, water conservation is becoming an ever-important practice for municipalities, institutions, and even individuals in pursuit of maintaining a sustainable freshwater supply. Reducing demand upon the water supply of a community remains the best practice for maintaining sustainable freshwater resources. For this reason, Illinois Wesleyan University is looking for ways to reduce its overall water demand. Through extensive archival research into water conservation strategies and the City of Bloomington water supply, in-depth interviews with key informants on Illinois Wesleyan's campus, and identification of 'model university water management plans', this project aims to create a comprehensive report that lays the foundation for the development of Illinois Wesleyan University's first water management plan.

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Introduction

"When the well is dry, we know the worth of water."
-Benjamin Franklin, Poor Richard's Almanac

Of all the vast amounts of water on Earth, only about 1% is freshwater, and only a fraction of this 1% is accessible and available for use by humankind via lakes, streams, and groundwater (Bouwer, 2000). As a basic necessity for human survival, demand for freshwater resources will always exist; however, as recent trends suggest, the existence of a sustainable freshwater supply may not. Population has been increasing exponentially, bringing along an increase in water demand. In the last century water use has increased at more than twice the rate of the world population (Zabarenko, 2011). At the same time freshwater resources are steadily being depleted due to pollution and climate change (UNESCO 2009). Due to these reasons, it will be necessary for municipalities, institutions, and even individuals to: acknowledge their own impact to this alarming problem, realize and respect the source of their local water; and learn ways and take actions to consume water more sustainably. This concept will need to be realized even by those who are seemingly far away from this problem.

The quote from Ben Franklin embodies one of the greatest difficulties facing the contemporary movement for water conservation. For many communities and populations throughout the world, water conservation does not appear to be a pressing issue, and is therefore often overlooked. We use water for so many activities throughout the day, yet many of us take it for granted. Its accessibility is made so easy that many forget that water is in fact a very finite, limited resource. During 2012, when central Illinois suffered from summer-long drought conditions, many residents were hit with a stark reminder of this very simple fact, raising some serious concerns about maintaining an adequate water supply in Bloomington, Illinois. The observed effects of the drought were a reminder that even seemingly plentiful water supplies can become fragile under the right conditions. When Lake Evergreen and Lake Bloomington, the two major sources from which Bloomington draws its water supplies, reached a combined 8 feet below normal level this summer, the community entered a "moderate drought" threat level accompanied by "voluntary restrictions". Mandatory restrictions for the community would have started kicking in when lake levels reached 10 feet below normal, raising the alarm for water conservation in the community (Wells 2012). Whether it is through a mismanaged water supply, inefficient infrastructure, or the habits and behaviors of individuals who consume it, water is wasted every day. Through proper knowledge and awareness of water conservation strategies this waste can be minimized and efficiency of water-use can be maximized.

The topic of water consumption at Illinois Wesleyan University is important as the University continues to strive to become a more sustainable campus. During the 2012 fiscal year, the University consumed approximately 36 million gallons of water, costing the University over $214,000 (Illinois Wesleyan University Water Bill 2012). Water demand on campus remains high. With the local community's water supply teetering on the edge of mandatory restrictions, Illinois Wesleyan must look to reduce its water demand and improve the efficiency of its water-use infrastructure if it wishes to meet its community's needs. To achieve this, a comprehensive knowledge of water conservation management practices is necessary.

The objective of this research project is to identify strategies for controlling the consumption of water, for reducing the loss or waste of water, and for maintaining or improving the efficient use of water on the Illinois Wesleyan University campus. Illinois Wesleyan is a small, liberal arts university in Bloomington, Illinois that is making efforts to become a more eco-conscious campus, yet Illinois Wesleyan still remains a large consumer of water in the Bloomington area. This leads to the overall research question: What are some feasible ways in which Illinois Wesleyan University can effectively reduce water consumption levels whether or not called upon by the City of Bloomington? By partnering up with the Director of Government and Community Relations at Illinois Wesleyan, this project aims to develop a solution to this question with the goal of an environmentally sound and economically feasible water conservation management plan.

In pursuit of an answer to the overall research question, many different research methods were used. The research and methods used in the completion of this project can be summarized in four steps including: (1) the literature review process; (2) exploring water conservation for universities; (3) in-depth interviews with key informants; and (4) exploration of Bloomington's water supply and drought measures. Each method contributed a wealth of knowledge to the research, ultimately culminating in the ability for this project to recommend further actions to guide the developments of a comprehensive water management plan on the Illinois Wesleyan Campus.

Literature Review

Extensive archival research was conducted into a database of existing literature regarding water conservation. Introducing the importance of water conservation establishes the significance of the opportunity presented to Illinois Wesleyan University to pursue water conservation efforts. Furthermore, the literature presents the concept of urban water management systems. Tracing the history of urban water management systems will give the reader a solid background into the development and necessity of current 'sustainable' water management models. Then, the research dives into the many water management strategies that can be employed for urban and residential areas to compile a comprehensive catalog for the reader to reference. This will include: indoor water conservation strategies, specifically retrofit programs; outdoor water conservation practices, specifically irrigation system hardware, landscape re-design, and efficient outdoor management practices; and leak repair and detection. Each sub-category will present associated costs and savings of each strategy, supported by case studies that are currently utilizing these strategies. After the literature review, this paper will introduce its research methodology section, explaining the process behind the project.

Importance of Water Conservation

Of all the vast amounts of water on Earth, only about 1% is freshwater, and only a fraction of this one percent is accessible and available for use by humankind via lakes, streams, and groundwater (Bouwer, 2000). Salt water and frozen freshwater make up the remaining supply, but are both virtually useless as potable water sources. As global population continuously rises along with a desired standard of living, the availability of freshwater across the globe is becoming an area of concern, especially in drought-prone regions. A recent study shows that the world's population is growing by about 80 million people per year, bringing along an increased freshwater demand of about 60 million cubic meters a year. This situation will only be intensified in the following decade with the effects of climate change, already contributing to a continuous reduction in surface freshwater over the past ten years (UNESCO, 2009). Many parts of the world have been facing challenges with fresh water supply for some time now, but as this seemingly abundant resource becomes even more threatened, it is no longer only the arid regions that are realizing the extreme value of sustainable management of water resources (O'Hara et al., 2008).

Communities across the globe, particularly in urban areas, are starting to face new challenges in maintaining a healthy, sustainable water supply making it more important than ever to pursue the improvement of urban water infrastructure. A recent study predicts that by 2030, the number of 'urban dwellers' is going to increase by 1.8 billion (since 2005), constituting sixty percent of the world's population (UNESCO, 2009). As a result, "A sustainable approach to water supply and ongoing security is becoming a focus around the world with a variety of urban water planning schemes, including source substitution, recycled use, and desalination" (Carragher et al., 2012). Despite a long standing framework for general 'sustainable development', as formally defined by the Brundtland Report in 1987, approaches to proper management of water resources has always remained a 'work-in progress' (United Nations 1987). Now, with the added pressure of an ever-dwindling freshwater resource supply and an exponentially increasing world population, the pursuit of sustainable water management practices has been reignited (Vedachalam et al. 2012).

The History of Urban Water Management

Water resource development for an early agricultural civilization was as simple as the choice of place in which these civilizations formed, which was often in regions where rainfall and runoff could be easily and reliably tapped. In order to reduce their vulnerability to irregular river flows and unpredictable rainfall, they began to invent ways of capturing, storing, cleaning, and redirecting freshwater resources (Gleick 2000). Water resource development advanced further with the first irrigation canals, allowing farmers to not only grow crops in drier regions but also to grow them for extended seasons. As cities grew, water supplies had to be brought from increasingly distant sources which required further advances in the sciences of civil engineering and hydrology (Gleick 1998).

This trend of modifying the hydrologic cycle has continued all the way through to our modern industrial societies through unprecedented construction of massive engineering projects for flood control, water supply, hydro power, and irrigation (Gleick, 1998). In the past century, the enormous expansion of water resources infrastructure has been driven by three contributing factors—population growth; changing standards of living; and expansion of agriculture. All have seen dramatic increases, "Between 1900 and 2000, the population of the world has grown from 1,600 million to over 6,000 million people. Land under irrigation increased from around fifty million hectares at the turn of the century to over 267 million hectares today" (Gleick 2000). These factors, along with others, have increased freshwater withdrawal seven times over, with costs that have not been purely economic, including the destruction of ecosystems, loss of fish species, disruption of sedimentation processes, and contamination of water sources (Rogers

1993). As social values and political conditions change, twentieth century approaches to water development have now stalled. “The old paradigm of relying on ever-larger numbers of dams, reservoirs, and aqueducts to capture, store, and move ever-larger fractions of freshwater run-off is beginning to fail for environmental, economic, and social reasons (Gleick 2000). This led to the formation of a new paradigm—the sustainable movement.

As stated earlier, the definition of sustainability in water resources has evolved over time, but it began with the basis that all human demands be met by natural supplies. The development of technology expanded this idea to include not just quantity but quality, thus redefining the concept (Hermanowicz 2008). The new concept of sustainable water resource development is defined as: “the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological systems that depend on it” (Gleick 2000; Roy et al. 2010). This major shift in our conceptual understanding of sustainable water resource development has produced a significant focus in sustainable water management strategies, many of which will be discussed in this paper.

Indoor Water-Use Conservation Strategies

Since the mid-1980’s, indoor residential water demand in many U.S. households has been declining. According to a study of residential water use conducted by the U.S. Department of Housing and Urban Development, the average 1984 (single family) household reported an indoor water use of 77.3 gpcd (Gallons per Capita per Day). This amount was then reduced by roughly 10% according to a more recent version of the study conducted in 1999 by the American Water Works Association (AWWA) which found an average gpcd of 69.3 (Mayer et al 1999).

This continuing trend of reduction in household water use can primarily be attributed to the steady improvements in the efficiency of plumbing fixtures and appliances. With each and every installation, such appliances are dramatically reducing water consumption across the globe. In 1992, the installation of efficient plumbing fixtures received a dramatic and permanent boost due to the passing of the Energy Policy Act. For the first time, the U.S. government established a maximum allowable water-flow rate for toilets, urinals, showerheads, and faucets. In line with the newly established ordinance, all public and private construction after 1992 was required to regulate the water-flow of its plumbing fixtures and appliances within the maximum allowed limits, thus improving the water efficient infrastructure of the nation (*Energy Policy Act* 1992). Even though all new construction would face regulation, existing plumbing infrastructure was allowed to remain, leaving a large potential for further improvement.

For this reason, reductions in indoor water consumption have continued to improve as more customers choose to upgrade to water efficient fixtures. Advancements in residential water efficiency can especially be observed in homes and institutions with outdated, high volume, or leaking fixtures (Perdue et al. 2009). Institutions and homes that fall into this category, and who are looking for significantly lower per-capita water-use rates, can turn to the process known as Retrofitting.

Retrofitting

Retrofitting is the process of implementing high efficiency water fixtures/appliances in households, by replacing existing, outdated plumbing equipment. Retrofit programs are permanent, one-time conservation measures that have little to no cost over their lifetimes (Jensen 1991). Retrofit programs are cost effective and useful in conserving water as shown in multiple case studies, which follow:

CASE STUDY In 1991, a New England apartment building underwent a retrofitting program that replaced existing fixtures with low-flow shower heads and faucet aerators. Over 150 apartments were retrofitted totaling a cost of $1,074. Within a single year, this retrofit program saved 1,725,000 gallons of water, $8,590 for energy, and $980 for water (Jensen 1991).

CASE STUDY From 1990 to 1993, the Massachusetts Water Resources Authority implemented "Operation Watersense"—a massive retrofit program involving 348,871 households throughout Boston. After handing out retrofit kits to participants (which included low-volume showerheads, faucet aerators, and toilet displacement devices), the study reported net reductions in water demand of 5.7% for single-family households and 10% four multifamily units—ending in a estimated program wide savings of roughly 5.0 million gallons per day (Operation Watersense 1996).

CASE STUDY Another case study installed low-flow showerheads and toilets in public housing in Marble Falls, Texas. In one year, this retrofit program saw an indoor per capita reduction in water use of 21% (Jensen 1991).

As one can see, a retrofit program can be any number of combinations of water efficient technologies. However, for the best results, a complete retrofit program that upgrades entire plumbing infrastructure is recommended. A complete retrofit program has the potential to reduce average indoor water-use from 69.3 gpcd to 45.2 gpcd—a 35% reduction in demand per capita (Perdue et al 2009). Reductions of this level show the large potential from implementing retrofit programs in a water management plan. To offer evidence in support of this claim, the section on retrofitting will split into detailed subsections of current water-efficient technologies for toilets, urinals, showerheads, faucets, and washing machines (Vickers 2001; Perdue et. al 2009).

Retrofitting: Toilets

Toilets account for about 26.7% of total indoor water use in a typical single-family home. Averaging about 18.5 gpcd, water use by toilets holds the top spot as the largest source of indoor residential water use (Mayer et al. 1999; Perdue et al. 2009). According to Jensen, the average American uses about 9,000 gallons of water to flush 230 gallons of waste down the toilet per year, combining to a total of 4.8 billion gallons of water each year per person (Jensen 1991). Naturally, this value is as high as it is due partially to the frequency of toilets use, as the average person flushes the toilet 5.1 times per day (Mayer et al. 1999). However, this value remains especially high because many of the toilets being flushed are outdated. Such a large source of water consumption deserves attention from any water conservation program, and improvements in the efficiency of toilets presents a great potential for overall water-use reductions in this area.

As stated, residential water demand for toilet use remains high, in part, because of outdated fixtures across the nation. Many of these toilets still in operation were manufactured before the Energy Policy Act was passed in 1992, meaning they still use 3.5 gallons or more per flush. The Energy Policy Act holds the single greatest impact on indoor residential water demand across all areas, including toilets (*Energy Policy Act* 1992). Due to the passing of this act, the amount of water being consumed by toilets has already been on the decline In 1984 for example, a study found an average of 5.5 gallons were used per flush (Residential Water 1984). By 1999, this value had decreased to an average flush volume of 3.48 gallons per flush as newer high efficiency toilets began replacing older high volume fixtures (Mayer et al. 1999). This value shows potential for further reduction as more efficient toilets with new technologies are installed nationwide. For example, according to the Environmental Protection Agency's website, implementing newer high-efficiency toilets that use 1.6 gallons per flush could reduce the average flush volume value by half, saving nearly two billion gallons per day across the country ("Conserving Water" 2010). This retrofitting section on toilets will describe three measures that can be implemented in a water management plan: low-volume toilets, waterless and composting toilets, and toilet displacement devices.

Low-Volume Toilets

Low-volume toilets are typically toilets that use 1.6 or less gallons of water per flush. They are available in the same operating designs as high-volume fixtures; they just simply use less water. They are commonly available in three basic types of design: low-volume gravity-tank toilets, low-volume flushometer-tank (pressurized) toilets, and low-volume flushometer-valve toilets. Each of these designs has further potential for augmentation such as dual flush capability, vacuum assistance, or the installation of automatic flushing sensors (Perdue et al. 2009). Findings from a few major case studies of retrofit programs that implemented low-volume toilets follow:

CASE STUDY One case study involves a residential and commercial rebate program conducted and sponsored by the New York City Department of Environmental Protection. In this program, over 1.3 million low-volume (1.6 gallons per flush) toilets were installed in New York City from 1994 to 1997. The installation of these toilets achieved an estimated water savings of 70 million gallons per day at about 53.8 gallons saved per day per fixture. Many of the toilets replaced were older toilets that flushed 5 to 7 gallons per flush, which is why the savings per fixture was so high. Overall, the 67 apartment buildings surveyed reported an astounding 29% reduction in water-use (Evaluation of New York 1996) (U.S. General Accounting 2000).

CASE STUDY A second case study looks to a program by the Los Angeles Department of Water and Power that has installed over 900,000 low-volume toilets. Total water savings from the program is estimated at 28.7 million gallons per day at about 31.7 gallons per day per fixture. Totaling a cost of $107 million, the program has more than paid for itself in water-savings and avoided costs for sewer infrastructure upgrades (A Survey 1995; U.S. General Accounting 2000).

Low-flow toilets are the most convenient devices to install when upgrading outdated devices due to their similarity in function and design. Being the same design, users of the fixture would experience minimal to no behavior change in their toilet use practices (Vickers 2001). However, there are other options that sacrifice convenience for optimal water-use reduction, such as waterless toilets.

Waterless Toilets

The concept of waterless toilets is a very foreign concept for the majority of Americans. Although they have been around for over 50 years, they represent a very small percentage of toilets installed. The two types typically in use are composting and incinerator units; each requiring, as the concept suggests, no water for flushing (Wilcox 1996). Since composting and incinerator toilets require no water and are not 'flushed', they require no connection to a plumbing system, nor do they need sewer or septic hook-up capability. Each is a self-containing system that disposes of waste through either the process of natural decomposition or the application of extreme heat and pressure to 'incinerate' waste (Wilcox 1996).

Due to their design, waterless toilets reduce water-use and leakage by virtually 100%. It is recorded that the average savings per capita in residences or institutions that install waterless toilets is 17.9 gpcd, equivalent to an annual savings of 6,515 gallons per capita per year. In addition to water savings, waterless toilets provide sewer and energy savings, as well as a total reduction to septic system infrastructure since no waste will need to undergo treatment (Perdue et al. 2009). Despite the number of benefits and savings presented by waterless toilets, the costs associated with installing them are considerably more than conventional toilets. Purchasing and installing waterless toilets is expensive—an estimated cost of $2,000-$16,000 for a single-family home (Perdue et al. 2009).

Other than the novelty of implementing waterless toilets, there isn't much practical use due to the cost. There are many other options to reduce toiler water demand that are easier to install and have a much short return of investment period. For this reason, composting toilets will not be a focus in the literature review. Examples of the more practical retrofit measures follow.

Toilet Retrofit Devices

At the other end of the cost-scale are toilet retrofit devices. Toilet retrofit devices are often applied to residential and nonresidential water management programs that either don't have the capability or don't have the funds to completely replace existing high-volume fixtures. Instead, this retrofitting option simply installs features that augment flushing capabilities of existing 'high-volume' fixtures. Fixtures that use 3.5 gallons or more per flush can be retrofitted by a variety of devices/processes including: displacement devices (bottles and bags or "bladders"), toilet dams (plastic or metal), early closure devices, dual-flush adapters, or by making efficiency adjustments. However, this category of retrofitting cannot be applied to toilets that already flush at 1.6 gallons due to the resulting difficulty in flushing of the 'weakened toilet' (Perdue et al. 2009). Essentially, the older, more higher-volume the fixture is the greater the savings experienced with the use of toilet retrofitting devices. The average savings varies from 0.5 to 1.5 gallons per flush depending upon the device installed and the toilet being augmented

(Konen et al. 1992). Findings from a few major case studies of retrofit programs that implemented toilet retrofit devices follow:

CASE STUDY In 1992, a study conducted by the Stevens Institute of Technology was able to find and report the average water savings of more than 30 retrofitting devices/procedures. Each measure was applied to toilet models ranging from 3.5 gallons per flush to 7.0 gallons per flush, resulting in water savings from 0.60 to 1.40 gallons per flush. The study's findings of potential water savings from each device and associated cost for hardware can be estimated as follows:

Toilet Retrofit Device	Water Savings (gpf)	Hardware Costs ($)
Displacement devices	0.5 to 1.5 gpf	$0.59 to $1.50
Toilet dams	0.5 to 1.0 gpf	$3 to $4
Early closure devices	1.0 to 1.5 gpf	$2.50 to $4
Dual-flush adapters	0.6 to 1.2 gpf	$8 to $20
Flush-valve adjustment	0.5 to 1.0 gpf	$20-$25

(Konen et al. 1992)(Perdue et al. 2009)

CASE STUDY A second case study involving toilet retrofit devices looks at a program implemented by the Norwood Hospital in Massachusetts. The program consisted of installing water-efficient flush valves on toilets and urinals in addition to installing low-volume aerators on all restroom faucets. Total costs for purchasing and installing devices was $8,092, but reduced annual water consumption by 3 million gallons, resulting in an annual water and sewer savings of $19,679. So the payback period found in this study was less than six months (Reducing Costs 1992)

Toilet retrofit devices remain extremely practical as measures to implement in a water management plan that is looking for a quick return on investment and even quicker results. Indoor residential water demand from toilet-use is a category of high priority for even the most basic of water management plans. Review of literature has identified numerous retrofit strategies to reduce toilet-use water demand including: low-volume toilets, waterless toilets, and toilet retrofit devices. The following retrofit section will address a similar fixture additionally found in lavatories.

Retrofitting: Urinals

Another form of the toilet—with similarities in frequency of use—is the urinal. Not commonly designed for a residential setting, urinals are often seen installed in the nonresidential male lavatories of public institutions such as offices buildings, dormitories, sports arenas, airports and many other facilities. As a substantial source of water consumption for nonresidential settings, urinals deserve equal attention with toilets for any water conservation program dealing with nonresidential institutions.

Just like toilets, urinal water-flow became regulated after the Energy Policy Act was passed in 1992. Due to the passing of this act, a series of technologic advancements drastically improved the water-efficiency of urinals (*Energy Policy Act* 1992). For example, water demand of urinal-use was found to be anywhere from 3.0 to 9.0 gpcd when outdated, high-volume fixtures were installed. However, when a 1.0 gpf 'low-volume' fixture was used, water demand of urinal-use dropped to 2.0 gpcd (Behling et al. 1992). A possible 7.0 gpcd reduction in demand is hard to pass up when managing water consumption. So, as with toilets, improvements in urinal water-efficiency clearly present a solid potential for overall water-use reductions in this area. This retrofitting section on urinals will describe two measures that can be implemented in a nonresidential water management plan: low-volume urinals and waterless urinals.

Low-Volume Urinals

Since the Energy Policy Act was passed, all urinals that are sold, installed, or imported in the United States must be low-volume urinals, meaning they use about 1.0 gallons per flush or less. Replacement of high-volume fixtures with low-volume urinals is often a convenient option, requiring no modification to existing plumbing connections. While federal regulations dictate 'low-volume' to mean 1.0 gpf, urinals that use 1.5 gallons per flush will sometimes also be labeled as 'low-volume'. However, anything over 1.5 is considered high-volume and can reach 5.0 gallons per flush or more (Perdue et al. 2009). This ability to save 4.0 gallons per flush in some locations nationwide presents a strong potential for water savings. As stated earlier, one study shows that water-use of low-volume urinals in a nonresidential setting is about 2.0 gpcd, but jumps anywhere from 3.0 to 9.0 gpcd when an outdated high-volume urinal is installed (Behling et al. 1992). Such a dramatic difference in indoor water demand (7.0 gpcd) further supports the water-saving impacts of implementing low-volume urinals in nonresidential retrofit programs.

Waterless Urinals

Just like the waterless toilet, waterless urinals require no water for flushing, virtually reducing water consumption to 0.0 gallons per flush. At an estimated two flushes per capita per day, each waterless replacement of a 3.0 gpf model will save 6.0 gpcd—equaling an annual savings of 1,560 gallons per user (Perdue et al. 2009). Compared to a low-volume model, waterless urinals only save an additional 1.0 gpf. However, over time, this small savings adds up—especially when implemented in massive scale retrofit programs. Illminating the impact of waterless urinals on water savings, here are findings from a few case-study retrofit programs that implemented waterless urinals:

> CASE STUDY The San Diego Union High School District has been installing 'no-flush' urinals in its schools since 1993, totaling 20 fixtures. Upon conducting an evaluation of the fixtures, they found a water-savings of about 45,000 gallons per urinal annually. With the savings from the reduction in water use, all 20 fixtures net the district a totals savings of about $4,900 a year (Whitley 1996).

The very short period for full return of investment in waterless urinal retrofit programs can be seen through case studies as well:

CASE STUDY The Glen Canyon Dam Visitor Center in Arizona recently installed just 3 waterless urinals. These urinals are projected to save 675,000 gallons per year, resulting in a water savings of $830. If these projections ring true, the initial investment will be paid back in 3 years (Waterless Urinals 1997).

CASE STUDY NASA's report on its installation of 335 waterless urinals further supports the claim of a short-payback period for waterless urinals. They reported that full return of investment was achieved in 2.2 years (Sample Project 1996).

Although more common than the waterless toilet, the waterless urinal is still rarely implemented in nonresidential infrastructure, making studies—such as those above—just as rare. This is due to a few practical reasons. Cost-wise, waterless urinals require a somewhat high initial cost for hardware, quotes range from $350 to $600 per fixture (Perdue et al. 2009). In addition, since they are not connected to water pipes and they have no flush valve, waterless urinals are confusing and often need to have a notice posted on them to let users know just what they are. For these reasons, they are often overlooked as a viable option for upgrades in nonresidential retrofit programs. However, for those institutions choosing to install waterless urinals, the resulting substantial water savings—as seen in above case studies—more than makes up for the cost and foreignness of the device (Vickers 2001).

Although really only applicable to nonresidential settings, understanding water efficiency strategies for urinals has provided substantial insight into the similarities shared between residential and nonresidential retrofit programs (and was also necessary to include due to the institutional setting of this project). Clearly indoor water demand from urinal-use should be marked as a high priority category when developing a nonresidential water management plan. Review of literature has identified numerous retrofit strategies to reduce urinal-use water demand including: low-volume urinals and waterless urinals. The following retrofit section will address yet another substantial source of indoor water consumption.

Retrofitting: Showerheads

Showers account for about 16.8% of total indoor water use in a typical single-family home. At about 11.6 gpcd, water use by showerheads holds the spot of the third largest source of indoor residential water use (Mayer et al. 1999; Perdue et al. 2009). Nationwide, water use by showerheads totals about 1.2 trillion gallons of water consumed per year ("Conserving Water" 2010). This number is especially high due to the continued use of outdated fixtures across the nation. Such a large source of water consumption deserves attention from any water conservation program, and improvements in the efficiency of showerheads presents a strong potential for overall water-use reductions in this area. Due to the Energy Policy Act, the amount of water being consumed by showers has already been on the decline. In 1984, the average showerhead water-use in non-conserving homes was 16.3 gpcd, with an average flow rate of 3.4 gallons per minute (Residential Water 1984). The adoption of the Energy Policy Act, which required all showerheads sold, installed, or imported in the United States to be low-volume showerheads regulated to a maximum of 2.5 gallons per minute, led to a steady decline in the nationwide average of showerhead water demand (*Energy Policy Act* 1992). As stated earlier, this amount quickly became reduced to 11.6 gpcd with an average flow rate of 2.2 gallons per minute (Mayer et al. 1999). These rates show potential for further reduction as more residential and nonresidential retrofitting programs implement water-efficient showerheads within the nation's infrastructure. This showerhead retrofitting section highlights the savings and costs of low-volume showerheads; and suggests both retrofit devices and adjustments that can augment existing showerhead fixtures to a lower flow-rate.

Low-Volume Showerheads

Conventional showerheads use about 4.0 gallons of water per minute. New low-volume showerheads reduce this amount to 2.5 gallons per minute. According to Jensen, this saves approximately 20,000 gallons of water per year for a family of four and each showerhead only costs about $5 each (Jensen 1991). These showerheads improve water efficiency while still retaining the feeling of greater water-flow rates even though actual water flow is being suppressed. This illusion can be achieved through a number of features, and there are many design options available to be implemented in a retrofit program. A few of these water conserving features include:

<u>Aerating-Spray Showerheads</u>—mix air with fine water droplets which allow the spray to wet more surface areas while still retaining a lower flow rate than conventional fixtures.
<u>Atomizing Showerheads</u>—operate similarly by 'misting' its water-flow, enabling for a larger surface area to be hit.
<u>Pulsating Showerheads</u>—have variable spray and flow patterns. A massaging effect is acquired by pausing and releasing water in spurts.
<u>Temporary Shutoff Button</u>—is a feature that slows water-flow to a trickle when the user is shampooing or washing, thus saving water by shutting off flow entirely during these periods. So the user isn't blasted with uncomfortably hot or cold water upon resuming showering, this feature maintains the same mix of hot and cold water as before.

(Water Management 1994)

Reducing water consumption in showerheads doesn't mean sacrificing comfort, nor is it expensive. Showerheads rated at 1.5 to 2.5 gpm are estimated to cost anywhere from $4 to $8 each (cheaper when bought in bulk). In addition to being easy and inexpensive, installing low-volume showerheads shows positive results—translating to huge water savings in both residential and nonresidential settings. For example, replacing a 4.0 gallon per minute (gpm) fixture with a 2.5 gpm model will reduce daily water consumption by 5.3 gallons per person. While this daily savings may seem minimal, collectively it adds up to an annual savings of 1,935 gallons per person per year (Perdue et al. 2009). To support this estimation, actual savings from a series of case studies involving showerhead retrofit programs follows:

CASE STUDY An athletic facility in Massachusetts replaced 35 4.0 gpm models with low-volume (2.5 gpm) fixtures for an initial cost of $300. Due to this investment, the facility experienced an annual water savings of 328,000 gallon a year, translating to an annual monetary savings of $3,330. They reported the payback on their investment was attained in a single month (MWRA 1995)

CASE STUDY Data records for over 70,000 residential units in New York City report an estimated average water savings of 12.4 gpcd for households with 2.5 gpm showerheads, compared to household with outdated fixtures (Nechamen et al. 1996)

CASE STUDY A case study conducted in 1990 developed a model to estimate water use savings resulting from the installation of low-flow showerheads in residential buildings. In this study, 308 single family residences were analyzed with results estimating that indoor water use per person saw a drop of 6.4% (Whitcomb, 1990)

Showerhead Retrofit Devices and Adjustments

In addition to installing a whole new fixture, a retrofit program can opt to augment existing fixtures by either installing showerhead retrofit devices or by making adjustments to the current plumbing. Shower retrofit devices include installing cut-off valves or flow restrictors; however, neither is a generally acceptable conservation measure due to user dissatisfaction. These measures should only be implemented in times of extreme water shortage (AWWA 1993). Simple adjustments to plumbing that result in the conservation of showerhead water-use include reducing the water pressure of a fixture and lowering the hot water temperature setting. However, the reliability of both methods is questionable as neither adjustment will necessarily cause less water use overall (Vickers 2001).

Retrofitting: Faucets

Kitchen and lavatory faucets account for about 15.7% of total indoor water use in a typical single-family home. At about 10.9 gpcd, water use by faucets holds the spot of the fourth largest source of indoor residential water use (Mayer et al. 1999; Perdue et al. 2009). Nationwide, water use by showerheads totals more than one trillion gallons in the United States per year (Jensen 1991). This number remains especially high due to the use of outdated fixtures across the nation. As retrofit programs attempt to reduce indoor water use across the board, even the fourth largest source deserves to be addressed by any strong retrofit program, and improvements in the efficiency of faucets presents a great potential for overall water-use reductions in this area. Due to the Energy Policy Act, the amount of water being consumed by faucets has already been on the decline. In 1984, the average faucet water-use in non-conserving homes was 10.3 gpcd, with an average flow rate of 2.6 gallons per minute (Residential Water 1984). Upon passing of the Energy Policy Act, which required that all faucets sold, installed, or imported in the United States to be ‘low-volume’ faucets regulated to a maximum of 2.5 gallons per minute, the nationwide average began to drop (*Energy Policy Act* 1992). Since the act was passed the average volume of residential faucets has already dropped to 1.34 gallons per minute (Mayer et al. 1999). These rates show potential for further reduction as more residential and non-residential retrofitting programs implement water-efficient faucets. This faucet retrofitting section highlights the savings and costs of low-volume faucets, and suggests retrofit devices that can augment existing faucet fixtures to attain a lower flow-rate.

Low-Volume Faucets

Conventional, older faucets use 3.0 to 5.0 gallons of water per minute (gpm). Choosing to install newer low-volume faucets, which use a maximum of 2.5 gpm (or 2.2 gpm when running at an air pressure of 60 psi), can reduce a sink’s overall water-flow by 30% or more (Jensen

1991). Some faucets are even available at maximum flows of 2.0 or even 1.5 gpm (Perdue et al. 2009). According to the Environmental Protection Agency's website, if every bathroom sink in the United States installed a high-efficiency, low-volume faucet; the United States would save over $350 million in water utility bills and more than 60 billion gallons of water annually ("Conserving Water" 2010). These faucets improve water efficiency without sacrificing performance through different measures such as aeration, flow-control devices, and spray features. Installation of such technology yields both monetary and water savings to the user, even when replacing a model with a flow rate of 3.0 gpm. For example, a 2.5 gpm low-volume model compared to a 3.0 gpm model saves 2.7 gpcd—adding up to an yearly savings of 986 gallons per user. Retrofitting even more outdated equipment yields even greater results. For example, replacing a pre-1980 faucet that uses up to 5.0 gpm gives an annual water savings of 4,928 gallons per user (Perdue et al. 2009). Cost of hardware for installing low-volume faucets is fairly expensive, as each new lavatory faucet is quoted to cost anywhere from $40-$150. However, similar to other retrofit options, over time this investment will pay for itself in water savings. A case study that supports this claim follows:

> CASE STUDY In Dorchester, Massachusetts, the Carney Hospital undertook a massive retrofit program to upgrade all patient and examination room faucets to low-volume faucets. These fixtures were outdated with a water flow of 5.0 gpm. The new low-volume faucets installed had a flow of 1.5 gpm, reducing flow by 3.5 gpm per faucet. By using an estimate that each faucet would be used for 25 minutes a day, the study found that each sink saved the hospital 88 gallons per day, equivalent to 32,000 gallons per year. This massive retrofit effort was reported to return its investment in less than one month due to water and hot water energy savings, which were quoted at $280 annually per sink (MWRA 1994).

The study above not only shows the significance of overall reductions in water-flow, it also displays the usefulness and flexibility of water conservation plans to control target consumption hotspots.

Faucet Retrofit Devices

Similar to toilets and showerheads, existing faucets can be augmented using low-volume retrofit devices. The Massachusetts's hospital, in the case study above, experienced such a quick reimbursement because rather than suffer the costs of installing brand new fixtures ($40-150), they installed 1.5 gpm 'flow control devices' totaling just $12 for the purchase and installation of each device (MWRA 1994). Installing retrofit devices to existing fixtures is often less expensive, yet usually yields nearly equal results. Faucets can be retrofitted with aerators or a series of flow control features. Faucet aerators are devices that break the flowing water into a mist that reduces water use while still maintaining wetting effectiveness. They are inexpensive, available in a variety of spray patterns, and; by limiting flows to 1.5 to 2.5 gpm, they can reduce faucet water use by as much as sixty percent while still maintaining a strong flow (Jensen 1991; Vickers 2001). Similarly, flow control features operate by reducing flow and disallowing unnecessary use. Since they operate only when needed, they are generally considered very efficient. Their water-use efficiency, which varies amongst type, depends on two factors; the flow rate and the length of time they are set to run (Perdue et al. 2009):

Metered-Valve Faucets—devices set to deliver a predetermined amount of water before shutting themselves off. User must press again if more water is needed.
Self-Closing Faucets—similar to metered-valve, these devices shut themselves off automatically when the user releases a spring-loaded knob. These can also be set to be delayed, operating on timed cycles (ex. 10 second delivery).
Sensor-Activated Faucets—electronic devices, usually containing light or motion sensors which detect hands or other objects in front of them. They begin delivering water until the user steps away, and then they shut off automatically

(Perdue et al. 2009)

Faucet retrofit devices remain extremely practical as measures to implement in a water management plan that is looking for quick, inexpensive results. Indoor residential water demand from faucet-use is clearly a category of high priority for even the most basic of water management plans. Review of literature has identified numerous retrofit strategies to reduce faucet-use water demand such as installing low-volume faucets and augmenting existing fixtures with faucet retrofit devices. The next and final section of retrofitting will complete the coverage of indoor residential water-use hotspots.

Retrofitting: Washing Machines

Washing machines account for about 21.7% of total indoor water use in a typical single-family home. At about 15.0 gpcd, water use by washing machines holds the spot of the second largest source of indoor residential water use (Mayer et al. 1999; Perdue et al. 2009). Due to the communal nature of washing machines, the gpcd for washing machine usage is a much harder value to conceptualize than the gpcd values for toilet, showerhead, or faucet use. Research shows that washing machines are used much more infrequently than the other appliances mentioned above. According to a study conducted by the American Water Works Association (AWWA), residential washing machine usage averages 0.37 loads per person per day (Mayer et al. 1999). At well less than a single load per day, it's not the frequency of use that establishes washing machines' second place standing—it's the vast amount of water consumed per load. The AWWA study reported the nationwide average for water consumption per load to be 41 gallons (gpl). Despite extreme improvements in water efficiency of washing machines due to new technology, this average remains especially high. This is because there exists a huge gap between conventional, 'top-loading' washers still in use and new high-efficiency washing machines. For example, the typical conventional washing machine installed since the 1980's uses an estimated average of 51 gpl—giving users of these washers a residential water demand of 18.9 gpcd ("Washing Machines" 1997). On the other end, great potential exists for continued reduction in water-use, as users of new high-efficiency washing machines have a much lower residential water demand of 10.0 gpcd. High-efficiency residential washing machines use a maximum of 27.0 gpl, which is a vast improvement from conventional models (Vickers 2001). As more residential and non-residential retrofit programs replace existing conventional models with high-efficiency models, nationwide gpl and gpcd will continue to decrease. This washing machine retrofitting section will describe: high-efficiency washing machines, along with associated cost and savings; the ENERGY STAR ® Partnership Program, with its top tier efficient washing machine; and conclude with efficient water-use practices for washing machines.

High-Efficiency Washing Machines

Sometimes referred to as high-performance or "tumble" washers, high-efficiency washing machines are necessary in any retrofit program aiming to reduce overall water demand. As stated earlier, the average washing machine uses about 41.0 gpl. According to the Environmental Protection Agency's website, high-efficiency washing machines use 35% to 50% less water per load, as well as 50% less energy per load ("Conserving Water" 2010). Replacing a conventional, high-volume washer that uses 39.0 gpl with a 27.0 gpl model is estimated to save an average of 4.4 gpcd. Annually, this water-savings ends up being about 1,621 gallons per person (Vickers 2001). Further evidence of the impact of high-efficiency washing machines on residential water demand can be seen in a study conducted by the Department of Energy in 1998:

> CASE STUDY
>
> The purpose of this study was to compare and explore the water-use demands between conventional, high-volume, vertical-axis washers and high-efficiency machines. When 103 washers averaging a water-use of 41.5 gpl were replaced by the new machines, participants reported an average reduction in demand to 25.8 gpl—translating to water savings of 38% (Tomlinson et al. 1998).

Savings experienced in water and energy translates to money saved as seen in many case studies throughout this paper. Monetary savings are particularly important for these washers because in addition to high-efficiency, they also have high initial hardware costs. Retailing anywhere from $600-$1,100 (almost double the price of conventional washers), high-efficiency washers require a substantial initial investment. However, reported annual savings on water, energy, and detergent costs are estimated at $80 to $100 making the return of investment period about two to four years (Vickers 2001).

ENERGY STAR® Partnership Program

Since the mid 1990's, both the design and efficiency of residential washing machines has improved dramatically. Unlike the rest of the fixtures in this literature review, these improvements were not prompted by the passing of Energy Policy Act, in fact, a federal regulation on maximum water demand for washing machines does not even exist (*Energy Policy Act* 1992). Instead, these improvements were accelerated, for the most part, by the Department of Energy's ENERGY STAR ® Partnership Program which raised the standards of the washing machine market since its creation (Edgemon et al. 1998).

As of 2000, only 10% of washers in the United States met the ENERGY STAR standards, leaving the remaining 90% as top-loading units (Consortium 2000). The number of outdated washing machines has been steadily declining since 2000; according to the ENERGY STAR website, "It's estimated that there are 76 million top-loading washers with agitators, 25 million of which are at least 10 years old, still in use across the country… Together, these inefficient washers cost consumers $2.8 billion each year in energy and water" (www.energystar.gov). ENERGY STAR washing machines now lead the market by further improving high-efficiency washers, in fact there is a full-size certified washing machine that uses only 15.0 gpl. To capture the vast potential that exists by including these high-efficiency washing machines in a retrofit program, their site claims that: “If every clothes washer purchased in the U.S. this year earned the ENERGY STAR, we would save 540 million kWh (kilowatts per hour) of electricity, 20 billion gallons of water, and 1.4 trillion BTUs of natural gas every year, resulting in energy bill savings of about $250 million, every year” (www.energystar.gov).

Washing Machine Water-Efficiency Practices

Regardless of whether the washing machines included by the retrofit program are high-volume, high-efficiency, or the leading ENERY STAR model, there are several conservation behaviors and practices that will optimize the efficiency of the appliance:

1.) Operate the washer with full loads only.
2.) For washers with variable settings for water volume, select the minimum amount required per load.
3.) Pretreat stains to avoid rewashing.
4.) Use the shortest wash cycle for lightly soiled loads because this uses less water than most “normal” and permanent-press wash cycles
5.) Check hoses regularly for cracks that could result in water leaks or bursts.

(Perdue et al. 2009)

These practices and behaviors should be posted as notices near the appliances to help guide users, thus optimizing the water efficiency of whichever washing machine is included in the retrofit program.

Outdoor Water-Use Conservation Strategies

According to the U.S. Geological Survey (USGS), of the 26 billion gallons per day attributed to residential water demand in the United States, outdoor water-use comprises about 7.8 billion of those gallons—about 30% of overall use. The study goes on to estimate the average gpcd in the United States at 101 gpcd (Solley et al. 1998). Combined with a separate study that reports average indoor-use at 69.3 gpcd, approximately 31.7 gpcd is left to be devoted to outdoor water-uses (Mayer et al. 1999). Outdoor uses can include cleaning, car washing, swimming pools, and many others; however, the majority (about 80-90%) of this outdoor water-use component is devoted to watering lawns, plants, and gardens (Vickers 2001).

This number remains particularly high because for the majority of residential and institutional outdoor areas, current landscape design and irrigation practices use water inefficiently. There are many costs and benefits to these practices, but years ago a trend was set where the costs became outweighed by the perceived benefits. These functional, recreational, aesthetic, and economic benefits of excessively irrigated landscapes were perceived as being well worth the costs, which included increased pollution from lawn chemicals, increased water costs, and increased demand and depletion of water supply (Vickers 2001). However, as the dwindling water resources of regions teach the importance of water conservation, this trend is being reversed.

There are many water conservation strategies available for municipal, residential, or institutional reductions in outdoor water-use. These strategies can range in difficulty and cost, including; simple management practices, such as maintaining proper scheduling for irrigation; or expensive hardware improvements, such as installing new efficient irrigation systems or redesigning landscapes. Overall, comprehensive outdoor water demand management plans have the potential to reduce average gpcd by 20% or more (Vickers 2001). To offer evidence in support of this claim, the section on outdoor water conservation strategies will split into four detailed subsections of current water-efficient options including: irrigation hardware improvements, efficient landscape re-design, and outdoor management practices. The following are some examples of studies and programs in each category as well as the potential savings that can be achieved.

Irrigation Hardware Improvements

Hardware devices that reduce water use in outdoor areas vary widely in cost and efficiency, but the main goal of such equipment is to ensure that water is applied only when and where it is needed. Measures that can reduce outdoor water-use demand include: improved landscape irrigation system design, the addition of water-efficient irrigation devices, and the implementation of water recycling systems, such as rainwater harvesting and greywater re-use, into existing water-use infrastructure.

Landscape Irrigation System Design

Although a “no watering” option does exist, it will be disregarded in this section due to its controversial nature to some people. Regardless, there still exist many options to improve irrigation system design. Conventional sprinkler systems can often cause run-off and water waste by overlapping each other and by overlapping paved areas such as sidewalks and roads. To minimize this waste, an initial strategy is the installation of sprinklers with variable spray patterns (Vickers 2001). Another option to reduce water demand is installing drip-irrigation systems for non-turf areas. Drip-irrigation systems are considered the most water-efficient type of automatic irrigation system, saving up to 75% of the amount of water used by conventional sprinkler systems (SPUC 1998). Installation of a drip irrigation system is quoted at about $1.50 per square foot (Vickers 2001). Tending more towards turf-based areas is the third option for an irrigation system: the installation of a Weather-Sensitive Irrigation Controller Switch (WSICS). WSICS use an on-site rain gauge and weather sensor that receives continuous solar radiation, temperature, relative humidity, and wind data to deliver water only when necessary (Tsai et al 2011). A study conducted on 5 municipal athletic fields in Massachusetts, in which WSICS were installed, revealed a consistent reduction in water demand of 121,000 gallons per acre per year (Tsai et al. 2011).

Water-Efficient Irrigation Devices

Complete replacement of a conventional sprinkler system is an expensive procedure. A less expensive option utilized the addition of water-efficient devices and technologies to existing systems. These options include the installation of automatic rain shut-off devices and the use of soil moisture probes and sensors. Automatic rain shut-off devices are similar to WSICS in the sense that they automatically override scheduled irrigation when they sense imminent rainfall. Using the natural irrigation of rainfall eliminates over-irrigation during these periods and is estimated to reduce overall system use by 5 to 10% (SPUC 1998). Another option is the use of soil moisture probes and sensors. This option is used with automatic irrigation systems and by sensing current moisture conditions in the soil, it schedules irrigation by efficiently regulating moisture needs of the soil (Vickers 2001). Estimated savings from soil moisture sensors is anywhere from 10 to 29% (Wong 1999; Allen 1997).

Water Recycling Systems

Water Recycling Systems reduce the overall water demand of a system by incorporating the use of 'greenwater' as an alternative source of water. Greenwater is essentially rainwater and grey water that has been treated to an acceptable standard for non-potable use (Makropoulos et al 2008). Since the majority of outdoor water demand doesn't require a potable source, the use of recycled 'greenwater' systems such as rainwater harvesting and greywater reuse can dramatically improve outdoor water efficiency.

Rainwater Harvesting: Rainwater harvesting is an ancient practice that, fueled by water shortages from droughts and pollution, has been increasingly receiving attention around the world (Nolde 2007). As a green building practice, it is especially appealing because by reusing rainwater, it also reduces stromwater runoff and increases groundwater recharge (Sewell 2008). Rainwater harvesting systems vary in cost and sophistication, including a simple rerouting of gutters to covered trash barrels or the installation of massive cisterns. Regardless of what is used to store the rain, the most common way of collecting is from building rooftops (Vickers 2001). Using the example of a thunderstorm depositing just 1 inch of rain, a rooftop of 3,000 square feet can collect as much as 1,800 gallons of water (Vedachalam 2012). Another form of collection is installing a runoff recovery system and garden pond. A case study example follows:

CASE STUDY A 150 acre commercial nursery in Florida installed a runoff and recovery system which reuses rain and irrigation water. The system routes runoff from the entire 150 acre complex into two lined retention ponds, which then pump the reclaimed water through a sprinkler system. This system has reduced the complex's entire irrigation demand by 75%, saving approximately 150,000 gallons per day (Gonzalez 1996).

According to another study, the use of rainwater can reduce water demand by up to 100% for non-potable uses such as irrigation. This extreme value of conservation highly depends on amount of rainfall in the region and the size of the rainwater storage cistern implemented (SPUC 1998).

Greywater Reuse: The other water recycling system that can reduce outdoor water demand incorporates the reuse of greywater. Wastewater reclamation practices, which can be traced as far back as ancient Greece, are experiencing a surge in renewed interests due to similar reasons as rainwater harvesting (Vedachalam et al. 2012). These systems vary in size and complexity and can be included in multi-building installations all the way down to under-the-counter systems which do on-the-spot treatments (Sanders 2009). While it is preferable to incorporate the larger more-complex systems into new construction rather than retrofitting them later, the smaller ‘under-the-counter’ systems can be implemented at any time. According to the Irvine Ranch Water District, installation of such ‘dual-piping’ systems that reuse greywater typically increases the cost for plumbing of new construction by about 9% (Sanders 2009). However, these costs are mitigated by the potential savings in water. For example, each toilet that is ‘dual-plumbed’ within a greywater reuse systems has the potential to save an estimated 5,000 gallons per year. Furthermore, the University of California at Santa Barbara estimates that its greywater reuse system provides for approximately 90% of its irrigation and landscaping needs (Sanders 2009).

Efficient Landscape Re-design

Efficient landscaping re-design strategies are, in a way, very similar to retrofitting indoor fixtures with water savings technology (see *Retrofitting* section for more information). In the same fashion as a complete retrofitting program, a complete landscape re-design plan aims to reduce overall demand of outdoor water consumption infrastructure. Such a goal is essentially accomplished by ‘retrofitting two main aspects of the landscape: the choice of plants and the physical layout of the landscaped area.

Choice of Plants

Water needs of different plant species vary considerably, and some vegetation is better equipped to withstand the hot, dry time periods associated with droughts. Exotic plants often require a large amount of watering to stay healthy because, in reality, they aren’t indigenous to the specific areas climate. For this reason, implementing a water-efficient choice of plants into an outdoor water management plan can yield strong reductions in water demand. Supplemental irrigation can be reduced or even eliminated by strictly selecting native, drought-resistant, and low-water-use turf grasses, plants, and trees for a landscape (Vickers 2001; EPA). Water savings associated with the installation of such species varies depending on the previous water demand of plants that were replaced and the extent of such replanting, but according to one source, at least a 20% reduction in water-use can be expected (Vickers 2001). According to the California Department of Water Resources, expected savings from full replanting of areas can is estimated from 30% all the way to an 80% reduction in outdoor water demand (CDWR 2000). A case study which supports this claim follows:

CASE STUDY In 1996, the city of Albuquerque, New Mexico passed an ordinance that required all new landscaping to include no more than 20% high-water-plants. The study that was conducted, which compared pre-ordinance water-use to post-ordinance water-use of the residences found a decrease in water-use of over 36,000 gallons—a 28% reduction over just 6 months (Jenkins 1994).

In addition to the choice of plants, these plants must be established carefully, giving them the best chance to flourish and optimizing plant water-use efficiency. Procedures include: placing the plant in the right spot based on water, sun, and shade needs, as well as planting at the right depth and taking care not to damage the roots system (Vickers 2001).

Physical Layout of Landscaped Area

One of the most reliable ways of eliminating variability in effectiveness of outdoor conservation options is to modify the physical layout of landscaped areas. According to the Pacific Institute in California, "Proper landscape layout involves controlling the area and perimeter of turf, minimizing narrow paths or steep areas that cannot be irrigated efficiently, and grouping plants with similar irrigation needs" (Pacific Institute 2003). A comprehensive planning and design of a 'water-wise landscape' takes into account six conditions:

- The properties of existing soil, vegetation, and topology.
- The conditions of local climates and microclimates.
- The distribution and location of sunny and shady areas.
- Grouping plants in zones according to water-use (low, medium, and high-volume).
- The function of property (i.e. aesthetic, recreational, athletic, etc).
- The customer's maintenance infrastructure and preferences.

(Vickers 2001)

After careful evaluation of these six conditions is complete, the next step is to develop a master landscape plan. According to the California Department of Water Resources, water demand reductions from this strategy are estimated anywhere from 19 to 54% (CDWR 2000). Further benefits and savings associated with such a master plan are supported with the following case study involving efficient landscape re-design:

CASE STUDY A study conducted in Oakland, by the East Bay Municipal Utility District, surveyed more than 1,000 single family homes with both water conserving landscapes and traditional non-conserving landscapes. The study found a 42% reduction in outdoor water demand for the homes that had water-wise landscapes (*U.S. Water News* 1993).

CASE STUDY A program called "Xeriscape It!", conducted in Austin, Texas by the Environmental and Conversation Services Department, helped to implement 469 landscape re-design projects for homeowners. The resulting study of the program reported that 89% of participants saw a decrease in water demand, averaging a reduction of 214 gallons per day during peak summer months (City of Austin 1999).

The cost of redesigning a landscape can depend on several factors including, the size of areas being redesigned, the types of plants being purchased, labor and professional installation fees, and any irrigation retrofit or replacement costs (Vickers 2010).

Outdoor Management Practices

Regardless of the amount of investment put into a state-of-the-art irrigation system or the complete re-design of property into a water-wise landscape, no outdoor water management plan will optimize efficiency without the supplement of proper management practices. In this section, outdoor management practices that should be included with a water management fall into three categories: efficient irrigation scheduling, horticultural soil improvements, and regular system maintenance.

Efficient Irrigation Scheduling

Typically used on golf courses, athletic fields, and other large-turf covered areas; automatic irrigation systems often deliver water inefficiently due to poor scheduling. Managing a proper irrigation schedule means adjusting the *frequency* and *duration* of irrigations to a setting appropriate for turf, soil, and weather conditions. Inclusion of evapo-transpiration (ET) data is key in maintaining an irrigation system at peak efficiency as well. ET refers to water retention characteristics of the plants and soil (Vickers 2001). While most automatic irrigation systems average an efficiency of 50%, inclusion of such data can increase systems efficiency up to 90% (Beck 1996). To supplement improvements from proper data programming, an efficient irrigation schedule should include practices such as watering only in early morning hours and limiting watering cycles to a maximum of 15 to 30 minutes (Vickers 2001). Case studies that support the benefits and savings of efficient irrigation scheduling follow:

CASE STUDY A study conducted in Irvine, California installed ET controllers in the top-third of water-consuming residences. The study reported a savings of roughly 57 gallons per household per day—a reduction of 10% in each household's total water use or a 24% reduction in outdoor use (Hunt et al. 2001).

CASE STUDY Another study in California shows the impressive water savings from an ET-based irrigation schedule. In this study, 4 commercial sites (golf courses and athletic fields), averaging 35,000 square feet of irrigated area, were reprogrammed based on accurate ET data which reduced average water demand from 68 inches to 44 inches per season. Water saved equaled up to about 4,600 gallons per acre per day--$4,500 per acre per year (Gelinas et al. 1995).

Horticultural Soil Improvements

Soil quality increases landscape water-use efficiency by increasing a plant's ability to absorb and hold water effectively, making strong soil quality critical in optimizing outdoor water-use efficiency. It is important to analyze soil type and current soil quality before choosing which plants to include in a landscape and which soil improvement measures to implement. Soil improvement measures include: preserving existing topsoil, reducing soil compaction through aerating, and preparing soil with proper nutrients through compost and mulch supplements. Direct savings from making soil improvement are difficult to estimate due to the nature of the many indirect benefits associated. However, according to a study conducted by the Seattle Public Utilities Commission (SPUC), soil maintenance (including thatching, aerating, over-seeding, and top-dressing) is estimated to reduce water-use by 10% while amending soil with compost and mulch can reduce water-se by as much as 20% (SPUC 1998). A few case studies supporting these claims follow:

CASE STUDY The benefits of conducting a thorough analysis of soil properties can be seen in an Australian case study. In this study researchers used a soil-moisture monitoring system that precisely determined moisture content of soil at the root zone. Using this information, the irrigation system was accurately scheduled to keep soil moisture at optimal levels, while reducing water-use by 63% (Moller et al. 1996).

CASE STUDY Another study, conducted in Massachusetts, involved amending the soil of a portion of an athletic field complex with nutrient rich compost. The compost was rich in a substance called zeolite, which improved the moisture and nutrient retention of the soil, thus making the turf healthier. Compared to the control field, which did not receive the soil amendments, the zeolite soil saved 38,000 gallons per acre per year—a 37% reduction to irrigation demand (Tsai et al. 2011).

Regular System Maintenance

Successful management involves an understanding of the irrigation system, an ability to adapt landscape needs to various conditions, and an ability to recognize problems with the system and upkeep maintenance. Combining all aspects of outdoor landscape management practices can return staggering results in the water-efficiency of a landscape as can be seen in the following study conducted by Western Policy Research:

CASE STUDY This study evaluated the combined effects of irrigation scheduling, proper horticultural soil improvement, and system maintenance practices over 16 test sites. The study reported that within 5 years, water use of each sites dropped an average of 20%. Furthermore, excessive peak-season irrigation demand was reduced by as much as 50% (Western Policy Research 1997).

"The Handbook of Water Use and Conservation" lists a number of water-efficient landscape maintenance measures including:

Repair Broken Irrigation Systems Promptly—including broken sprinkler heads or leaking hoses.
Maintain Turf Grass Efficiently—including developing deeper roots, setting mower blades high, cutting grass only when dry, practicing grass cycling (using grass clippings to fertilize), and aerating the soil.
Fertilize Sparingly, Control Weeds, and Practice Integrated Pest Management

(Vickers 2001)

Research Design and Methodology

As the literature suggests, there exists a broad array of viable strategies that can be utilized to optimize water conservation practices. Through this extensive catalog, the literature identifies the clear potential that water conservation and efficiency improvements can have when implemented in a water management plan. Whether implemented large-scale at the municipal level or smaller-scale all the way down to an individual household, this perceived potential is ripe for the taking—especially for the closed-community setting and intellectual leadership offered by a campus such as Illinois Wesleyan University (IWU).

Illinois Wesleyan University

The small, private liberal-arts campus of Illinois Wesleyan University is located in Bloomington, Illinois. Purely composed of undergraduate degree seeking students, its population is 2,013 plus 183 faculty and staff members ("About IWU"). Illinois Wesleyan University is a four-year, residential university offering 24 living choices including 12 residence halls, 6 fraternities, 5 sororities and other off-campus houses to accommodate the vast majority of its students on or near campus. Although small in numbers, the student body is an active one, participating in 20 varsity sports and involved in 165 different student organizations ranging from student government to community service ("Student Life"). For example, a recent initiative of the Student Sierra Coalition (SSC) entitled "Taking Back the Tap" received a grant for installation of three new 'hydration stations' in their pursuit to ban bottled water on campus. Despite having a fairly 'conservative' population, there are still a large amount of 'liberal' thinkers when it comes to the importance of environmental protection.

There exist many resources that rank universities nationwide on their conservation and sustainability efforts. According to *College Sustainability Report Card*, which surveys, catalogs, and ranks the sustainability profiles of hundreds of universities in the United States and Canada; Illinois Wesleyan University received an overall grade of "C". While not a leader in environmental protection, the university has been making strides in the right direction. A few of these efforts, for example, include utilizing geothermal systems in new buildings, adding bike racks all over campus, increasing the number of recycling containers campus-wide, and going tray-less in the campus' main dining hall—amongst many others listed. Upon looking into the survey results (published on the *College Sustainability Report Card*'s website) to find information regarding current water conservation strategies on campus, it seemed only partially completed by Illinois Wesleyan. However, the survey did reveal claims of certain water conservation strategies under the 'Water Management' section. Under water-conservation technology, Illinois Wesleyan indicated the use of individual building water metering, low-flow showerheads, low-flow faucets, and ENERGY STAR front-loading laundry machines. Furthermore, Illinois Wesleyan had indicated using vegetated swales as a storm water management strategy (Sustainable Endowments Institute 2011). IWU is clearly an institution making efforts in the right direction. Enhanced awareness of environmental issues for students, staff, and especially administration has led to a steady improvement in IWU's sustainability ranking in recent years, a trend that will ideally continue for years to come.

Bloomington Water Situation

An apparent next step in the pursuit of Illinois Wesleyan's campus sustainability is in water conservation. As discernible from the literature, a water management plan is imperative to achieving reductions in water consumption levels. Many university campuses, mostly in arid regions such as the Southwest, have already developed a well-defined water management plan. However, unlike the majority of these schools whose circumstances necessitate attention to water consumption, Illinois Wesleyan University is located in a region accustomed to abundant water resources. The City of Bloomington relies on two surface water resources for its community potable water supply. Recently, concerns about these water supplies have arisen due to the 2012 summer-long drought, in which, "the combined level of Lake Bloomington and Evergreen Lake approached 7 1/2 feet below normal, just inches from the 8-foot deficit that will trigger the city's first wave of water-use restrictions" (Wells 2012). The drought months have since passed; only inducing water restrictions categorized as "voluntary" while an active threat. However, concerns were raised within the city on whether it and its residents would be ready to meet water restrictions if they became "mandatory". With Illinois Wesleyan University being a community leader and one of the top consumers of Bloomington's water supply (along with State Farm Headquarters), IWU administration decided that a comprehensive understanding of effective water conservation strategies would be necessary to develop an operating water management plan capable of meeting municipal drought restriction requirements—in case water resource circumstances ever necessitate *mandatory* measures.

Overview of Research Purpose and Question

This leads to the overarching research question driving this document: <u>What are some feasible ways in which Illinois Wesleyan University can effectively reduce water consumption levels if called upon by the City of Bloomington?</u>

The primary purpose of this research project was to both explore and catalog viable and proven water conservation methods, which Illinois Wesleyan University could implement on campus to effectively minimize water consumption levels. By partnering up with the Director of Government and Community Relations at Illinois Wesleyan, this project aims to meet its ultimate goal of collecting the information necessary to one day develop an environmentally sound and economically feasible water conservation management plan that: (1) effectively controls the consumption of water; (2) adequately reduces the loss or waste of water; and (3) capably maintains or improves the efficient use of water—on the Illinois Wesleyan University campus. In order to answer the research question and compile the proper catalog of information, the majority of this project's research strategies were qualitative, specifically in-depth interviews, use of web resources, and archival research.

Description of Research Design

The importance of water conservation, not only to Illinois Wesleyan University, but to the entire local community sparked interest in this project amongst IWU faculty, administration, and non-IWU community members. In early September, an initial meeting was held with the Director of Government and Community Relations at Illinois Wesleyan University. The purpose of this meeting was essentially a briefing about the idealized project, which explained a general guideline to what the University was looking for and what steps needed to be completed in order to execute the project professionally and up to University standards. The research and methods used in the completion of this project can be summarized into four steps including: (1) the literature review process; (2) exploring water conservation for universities; (3) in-depth interviews with key informants; and (4) exploration of Bloomington's water supply and drought measures.

Literature Review

The first step, as well as the most substantial step, was to research into existing literature to compile a comprehensive catalog of effective water conservation strategies. For the literature review, extensive archival research and use of web resources through the months of September and October produced the backbone of this project. Knowing the importance and history of water conservation policies, programs, technologies, and management provided a strong background to the significance of the problem that, in areas such as central Illinois, can be easily forgotten: the problem that water is, in fact, a finite, limited resource. Further exploration discovered a multitude of strategies that aim to serve as a solution to the problem mentioned by either reducing consumption of water, minimizing loss or waste of water, or improving efficiency of water usage. In the end, conducting this literature review has created a well of knowledge for this project to draw from and build upon by introducing numerous water management strategies, many of which seem practical for implementation on our own IWU campus.

University Water Conservation Efforts

The second step is an extension of the literature review in the sense that it further uses archival research, in conjunction with a search of web resources, to reveal the conservation efforts of universities similar to Illinois Wesleyan University. Compiling a database of evidence supporting the potential for water conservation in the university setting is imperative to developing a water management plan for IWU. The task will be able to identify model university water management plans for IWU to emulate as it pursues its own water management plan.

In-Depth Interviews with Key Informants

Turning this research project away from the literature, the next step switches its focus upon the Illinois Wesleyan campus. The first phase of the interview process comprises the majority of this portion, beginning with key informants on the Illinois Wesleyan University campus. Interviews were conducted thorough the month of November. The purpose for interviewing key informants on campus was (1) to gather and compile an understanding of water conservation awareness of department heads and key administrators, (2) to determine current or recent efforts to reduce water usage in each department, and (3) to identify current and past water distribution patterns. Millard Jorgenson, Director of Physical Plant; Mike Welsh, General Manager of Food Services; and Matthew Damschroder, Assistant Dean of Students—Office of Residential Life; were all interviewed. Choosing these department heads covered all the perceived hotspots for water consumption on a college campus. Welsh offered insight into the kitchens, Damschroder was very knowledgeable about residential efforts to promote water conservation, and Jorgenson was able to provide precise records of water distribution as well as irrigation practices. Understanding each department's awareness of the importance of water conservation and then learning their efforts to promote efficient water consumption within their department is an integral step in exploring ways to expand and diversify strategies.

Bloomington Water Supply and Drought Measures

The second phase of information needed to be gathered was further knowledge about the Bloomington water supply and municipals drought measures. The purpose of this portion of research is (1) to better illuminate the water resources available to the City of Bloomington, (2) to expose why insecurities about the water supply exist; and (3) to understand and dissect water source conservation measures, expected consumption cuts, and restriction levels during the threat of a draught. An understanding of what measures are in place to protect from reaching serious drought levels, as well as knowledge of what would be expected from the community in a time of drought will serve as important references for this document. Finding this information was meant be a two part process, consisting of interviews with local water resource personal and use of web resources. The interview process began by meeting with Karen Schmidt, an Ames librarian and Bloomington city council member. Karen proved to be a helpful resource, by putting me in contact with Craig Cummings, the Water Director for the City of Bloomington. An extensive interview with Craig was not able to occur due to availability and time constraints within the project. However, both Craig and Karen were able to reveal the information required by directing my research to the resources published through the City of Bloomington's Water Department. Drought reports, published throughout the 2012 summer; as well as the city's Interim Water Supply Plan, were consulted in this section of the research. These sources proved to be valuable web documents that gave a thorough explanation of drought measures.

Research Findings and Discussion

The final result of my research is derived from a five-part stepwise approach. First, an extensive amount of work went into compiling a list of top water conservation strategies being applied nationwide in residential, institutional, municipal settings (see Literature Review). Second, I conducted a search of web resources to explore and catalog a series of 'model university' case studies currently implementing many of the strategies explored within the literature review. Third, shifting focus to the Illinois Wesleyan Campus, a series of in-depth interviews with key personnel on campus revealed water distribution patterns and identified water consumption hotspots on campus. Fourth, research of documents published by the City of Bloomington's Water Department revealed a wealth of information regarding the city's water supply and expected drought measures. Finally, combining information gained from all previous steps, allowed the research to compile recommendations for action as Illinois Wesleyan University moves forward in pursuit of a sustainable water management plan.

The first task of my research was to gain a comprehensive knowledge of best management practices used across the country for water conservation. To achieve this, extensive archival research into a range of current water conservation practices was executed. The resulting outcome of such research efforts consists of a comprehensive catalog of proven and successful water conservation strategies, policies, and programs (See Literature Review). A brief summary of findings is included below.

Findings: Literature Review

The literature review's first step was identifying water-consumption hotspots for residential and nonresidential use. Hotspots are areas of high, and often inefficient, water-consumption—attributes which exhibit a strong potential for reductions in water-use, establishing these as target areas for water management plans. These areas identified include indoor water-use, outdoor water-use, and leaks within existing infrastructure.

Indoor water-use consists of about 69% of overall water consumption making it a high priority target for water management plans (Vickers 2001). Strategies explored for efficient management of indoor water-use consisted of retrofitting outdated plumbing infrastructure with current water-efficient technology. Technology covered in the literature included: toilets, urinals, showerheads, faucets, and washing machines. Individual costs and savings were reported for each technology and supported with model case studies of actual implementation. A review of the literature concluded that implementation of a full retrofit program in a water management plan could save an average of 14.1 gallons per capita per day (gpcd) (Vickers 2001).

Outdoor water-use is another high priority target of water management plans, consisting of about 31% of overall water consumption (Vickers 2001). Strategies explored for efficient management of outdoor water-use consisted of installing improvements to irrigation system hardware, re-designing to water-efficient landscapes, and implementing efficient outdoor management practices. Strategies involving improvements to irrigation system hardware covered in the literature included: the replacement of systems with state-of-the-art water-efficient irrigation technology and design; the retrofitting of existing systems with water-efficient irrigation devices; and the inclusion of water recycling systems, that use rainwater harvesting and greywater reuse, within existing irrigation infrastructure. Strategies involving re-designing water-efficient landscapes covered in the literature included: implementing a water-efficient choice of plants in the landscape; and re-designing the physical layout of the landscape itself. Finally, strategies involving the implementation of efficient outdoor management practices covered in the literature included: evapo-transpiration based irrigation scheduling; the use of horticultural soil improvements; and proper maintenance of water efficient landscapes and irrigation systems. The literature concluded a vast potential in water-savings when any combination of strategies explored are implemented into a water management plan.

The literature revealed the existence of a multitude of water conservation strategies that can be used to address hotspots of inefficient water consumption. However, many of the identified case studies used to support the success of such strategies were programs implemented in municipal or residential settings. As a research project aimed at institutional water conservation on the Illinois Wesleyan Campus, it was important to provide evidence in support of the successful juxtaposition of such strategies to residential-institutions similar to Illinois Wesleyan. For this, a search in to the water conservation efforts of other colleges and universities around the country was conducted.

Findings: University Water Conservation Efforts

The second task of my research plan was to explore the possible utility of strategies explored by the literature review in a university campus setting. To achieve this, a search of web resources revealed that many universities nationwide have been actively making water conservation efforts. Using the database of knowledge attained by the literature review, this project was able to: (1) compile a list of university case studies that have shown the success of water conservation strategies on a campus setting, and (2) identify examples of model universities that have developed and implemented comprehensive water management plans on their campuses. The result of such research is included below:

University Case Studies

University Case Study 1: Harvard College, Massachusetts

Harvard University has implemented a prime example of a toilet retrofit program that conserves water and reduces campus demand. Twenty-seven low-flow urinals and over 70 "dual-flush" toilets were installed in Harvard libraries in 2009. Each urinal saves approximately 7,000 gallons per year by using one-eighth the amount of water used by conventional urinals per flush. The "dual-flush" toilets, which allow users to select either a 1.6-gallon flush (for solid waste) or a 1.0 gallon flush (for liquid waste), reduce water consumption like all 1.6 gpf toilers but conserve even more every time the single gallon option is used.

(Harvard 2010)

University Case Study 2: Amherst College, Massachusetts

In 2005, Amherst College replaced all of the conventional washing machines in its dormitories with water conserving ENERGY STAR front-loading washing machines. These machines increased load capacity by 33% while reducing water consumption by 11 gallons per load and cutting detergent-use by 50%. It is estimated that these washing machines save approximately 580,000 gallons of water per year throughout campus. Not only that, but by extracting 33% more water each load, the machines reduce drying time, which in turn reduces energy used.

In addition, Amherst College has implemented an automatic field irrigation system that is estimated to save over 50% of the water used by the previous irrigation method. The system senses current weather conditions and waters accordingly, either watering daily or every three days depending on the level of heat (but always in the morning). The previous method for watering these fields was by manual spraying which wasted large amounts of water to overspray and evaporation.

(Green Amherst 2010)

University Case Study 3: University of Maryland, Maryland

The University of Maryland is one of the largest consumers of water in the state, using approximately 500 million gallons of water annually. This fact makes water conservation very important for the University. Since 2007, the University of Maryland has seen a reduction water demand of 14.4% due to implementing water saving technology around campus.

Low-flow fixtures have been installed in all residential halls, replacing toilets, urinals, showerheads, and faucets. In addition, all dishwashing units of dining halls have been replaced with steam heated equipment that require 30% less water to use—saving 960,000 gallons a year. The university also replaced water-cooled refrigerators with air-cooled technology, thus eliminating the water demand of such appliances—saving 150,000 gallons a year.

Supplementing water saving fixtures and appliances on the University of Maryland's campus are outdoor irrigation and landscaping practices. By installing automatic irrigation systems and introducing drought-tolerant native species of grass to the University golf course, the golf course has experienced a 38% reduction in water demand and saved over $30,000 a year in water bills.

(University of Maryland 2010)

University Case Study 4: Elizabethtown College, Pennsylvania

Elizabethtown College began enacting water conservation measures on its campus in 2001 due to persistent local area droughts. The college championed water conservation efforts in the community in order to save money, preserve the community's precious resources, and to exemplify stewardship for the environment as an intellectual leader. Its program included retrofitting existing fixtures and appliances, upgrading its current irrigation system, and encouraging community participation in water conservation.

The retrofitting plan consisted of two parts. First, every toilet and urinal throughout campus was retrofitted with low-flow fixtures. Overall, 444 toilets and 70 urinals were replaced, costing a total of $108,000 and saving 6.6 million gallons annually. This 30% reduction in water demand saves the College approximately $40,000 a year, giving a complete return of investment in just 2.7 years. The second part of the retrofit program included the replacement of conventional, top-loading washing machines with high-efficiency front-loading machines. The 32 new machines saved about 15.5 gallons per load, bringing total estimated savings to about 200,000 gallons and $21,000 a year.

The College installed a metered irrigation system that uses state-of-the-art features to automatically minimize water-use. Soil type and grass type are programmed into the system which has smart-sensing technology to automatically know irrigation needs. This feature coupled with a programmed schedule of evaporation rates ensures the system never wastes water due to overwatering. The study was unable to estimate savings from the system.

(Metro 2003)

The following studies involve university campuses where water conservation efforts have evolved from implementing isolated water conservation strategies to developing comprehensive water management plans. The following universities offer model programs as IWU develops it water management plan:

Model University Water Management Plans

<u>Model University 1</u>: Stanford University, California

One of the top comprehensive water management plans in the country belongs to Stanford University. Since 2001, Stanford's 'Water Conservation, Reuse, and Recycling' program has completed over 50 water-conservation projects on campus, encompassing all areas of water demand. In 2000, before the transformation, Stanford conducted a detailed water-audit that estimated a daily water consumption of 2.74 million gallons per day—an annual water demand of just over 1 billion gallons per year. By the 2009 school year, after the transformation, Stanford had reduced this amount to an estimated 2.15 million gallons per day—saving over 215 million gallons per year. Such an aggressive decrease in levels of water demand has earned Stanford numerous leadership awards and recognitions, both locally and nationally, including: the Clean Bay Award; the Santa Clara Valley Urban Runoff Pollution Prevention Program Award; and most notably, the Silicon Valley Water Conservation Award (Sustainable Stanford 2011; Water Sustainability 2011).

Central to the success of this program is the level of thoroughness in its overall management. For example, Stanford actively maintains over 1,600 water meters on campus. These meters are read monthly, the data is analyzed, and water use trends are evaluated; providing an updated and detailed database of measurements. Such extensive self-awareness of water demand lays the solid foundation on which Stanford's water management plan thrives, producing projects that span <u>all</u> departments to address <u>all</u> areas of water consumption. In addition, Stanford uses this information to encourage local community participation through a variety of educational and community awareness programs—creating an all-encompassing water management plan capable of reducing campus water consumption by 600,000 gallons per day. Such vast potential for water savings provides ample inspiration, making Stanford's water management plan one of the most important models for similar institutions, such as Illinois Wesleyan University, to emulate (Sustainable Stanford 2011; Water Sustainability 201).

The following section lists examples of many of the larger projects implemented in Stanford's water management plan. They've been grouped by project design into the following 4 categories: campus facilities, campus grounds, central infrastructure, and education and community outreach.

Conservation Projects—Campus Facilities

- At Stanford academic and residential facilities, more than 10,000 bathroom fixtures have been retrofitted with water efficient technology. Ninety-five percent of campus toilets have been retrofitted with low-volume 1.6 gpf toilets, 100% of campus showerheads are low-volume 2.5 gpm fixtures, and 100% of campus faucets are low-volume 1.5 gpm fixtures. These retrofits have cut water use by about 120 million gallons per year since 2001—a 37% reduction. Furthermore, in 2008, athletic facilities became testing grounds for newly developed water-efficient technology, retrofitted with toilets that only use 1.28 gpf and that only use .125 gpf.
- At Stanford medical-research facilities, 58 water-saving devices were installed on sterilizers reducing water-use by about 84,000 gallons per day—saving over 30 million gallons per year.
- At Stanford dining facilities, 100% of standard dishwashers have been replaced with trough conveyers which constantly recycle water, reducing water-use by about 142 gallons per hour—a 51 % reduction. Furthermore, all dishwashing spray heads have been retrofitted with low-flow valves.
- Throughout Stanford facilities, 100% of 'once-through' cooling systems have been replaced with 're-circulating' systems which reuse already cooled water, reducing water-use by about 174,000 gallons per day—saving over 63 million gallons per year.

(Sustainable Stanford 2011; Water Sustainability 2011)

Conservation Projects—Campus Grounds

- On Stanford's campus, non-potable water is used for irrigating all academic, residential, and athletic areas on campus. Most of these areas utilize a state-of-the-art irrigation controller system known as evapo-transpiration (ET). An ET system incorporates live weather data to automate irrigation so that grounds are watered only when needed with only as much water as necessary. By eradicating water waste from over irrigation, the ET system is estimated to save 230,000 gallons of water annually—reducing irrigation to large turf areas by about 25%.

- Stanford replaced 36 landscape zones (totaling over 2,500 square feet) of small grass areas throughout campus with water-efficient landscaping. Replacement of these areas with mulch and shrubs has been estimated to save about 100,000 gallons annually—reducing irrigation of these areas by about 10%.

(Sustainable Stanford 2011; Water Sustainability 2011)

Conservation Projects—Central Infrastructure

- At Stanford's Central Energy Facility, a project to reuse wastewater from the University's central cooling towers, in underway. Despite being managed efficiently, on an average day these towers discharge about 50,000 gallons of wastewater straight in the sanitary sewers. Since this water contains no solid waste, Stanford has begun to recycle this water for non-potable reuses such as toilet/urinal flushing and irrigation. Currently, only one other campus building is 'dual-plumbed' to use this water but the school is making efforts to include more.

(Water Sustainability 2011)

Conservation Projects—Educational and Community Outreach

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Educational outreach programs include:

- Stanford has implemented both a water-efficient technology demonstration program, and a water-wise demonstration garden on campus.
- Stanford has developed—and made available to the public—a set of water-efficient goals and benchmarks for all new construction on campus.
- Stanford redesigned its water billing statement format for campus residents. This new billing statement was made easy to understand by providing a graphics display of measurements. Doing so has encouraged residents to review their water use and consumption trends.
- Stanford gives a reusable thermos to all students enrolled on a meal plan. Doing so reduces the use of disposables and bottled water on campus. As an incentive, when students use the thermos at campus retail dining services, the students receive a discount. Bottled water has been eliminated on campus.

(Water Sustainability 2011)

Community outreach programs include:

- Stanford's 'Water Conservation Program' has been making monthly flyers—full of water saving ideas and tips—available to campus residents and nearby homeowners.
- Stanford provides free irrigation-runoff checking services to campus and nearby homeowners. In addition, they provide door-to-door notifications to homeowners about what they can do to avoid it.

- Stanford, in partnership with the local utility district, has conducted a number of water conservation programs to promote retrofitting to water-efficient technology; including awareness campaigns, free water audits, and rebate programs.

(Sustainable Stanford 2011; Water Sustainability 2011)

A Note on Management

As mentioned above, this is a well-managed water management plan, which is what allows it to encompass all aspects of water demand on Stanford campus. Extensive detail for the plan began with the initial “Water Conservation, Reuse and Recycling Master Plan”, written and published in 2003. In this original document; an outline of its goals is clearly defined and substantial research including a very thorough description of campus water demand trends in included. Even though Stanford’s water management plan evolved and expanded upon the original document, the Master Plan remained a crucial and necessary step in founding one of the most successful water management plans ever (Stanford Master Plan 2003).

(The full document can be found on the www.stanford.edu website)

Model University 2: Duke University, North Carolina

As Illinois Wesleyan University moves forward in pursuit of better water conservation practices, it is important to look to a multitude of case studies for emulation. The second model university’s water management plan belongs to Duke University. While not as comprehensive as Stanford’s, Duke’s management plan still provides further insight into the potential impact of implementing water conservation strategies in a campus setting. While exploring model university water management plans, certain models were chosen to be included for a number of reasons, such as success—as seen by the inclusion of Stanford. In addition to success, this research placed a strong importance on schools that shared conditions similar to those of Illinois Wesleyan University. It is for the latter reasoning that the water management plan of Duke University is included.

Exploring Duke University as a case study revealed a parallel to the purpose of my research for Illinois Wesleyan University in the sense of how Duke’s water management plan came to be. Like Bloomington’s current situation, the city of Durham, North Carolina (home to Duke University) underwent a summer-long drought in 2005. During this summer, the city entered a stage III drought alert and enacted moderate mandatory conservation measures which required the university to cut daily water usage by 30% or more. This prompted the university into immediate action, and Duke was able to meet the temporary restrictions (Dickinson 2005). However, this was not the first time, nor the last time, the city Durham had experienced a mandatory restriction causing drought. In 2007, another more severe drought put the city under a lever 4 drought alert, requiring Duke to meet mandatory restrictions yet again. As the leading water consumer of Durham—with a water demand of approximately 449 million gallons per year; Duke University decided it was time to take steps towards a permanent water management plan (Duke Sustainability 2011).

Duke University has already done the exact process of which Illinois Wesleyan University is currently beginning to initiate. For this reason, Duke was included in my research as the second model water management. That being said, while not up to Stanford's standards, Duke's water management plan is still an inarguable success. Since 2006, Duke has reduced its overall water-demand by nearly 200 million gallons per year—a 30% reduction in water consumption. Even more impressively, these results were achieved despite expanding campus grounds by 500,000 square feet and adding hundreds of students to enrollment (Roth 2012). Duke's water conservation initiatives really took off after the summer-drought of 2007 when the University consulted a local water conservation group to analyze and catalog all potable water demand on campus. According to Duke's online Water Conservation page, upon receiving this water demand analysis, "Duke reduced its water use by 50 percent month over month from the previous year during the drought" (Duke Sustainability 2011). Furthermore, "In the years following the drought, there has been an estimated sustained reduction in water consumption of 35 percent" (Duke Sustainability 2011). Many of the measures listed below were first initiated following the drought.

The following section lists many examples of the larger projects implemented in Duke's water management plan. I've grouped them by project design into the following 4 categories: campus facilities, campus grounds, central infrastructure, and education and community outreach.

Conservation Projects—Campus Facilities

- Duke has implemented a retrofit program to replace existing outdated fixtures. So far, the university has installed: over 3,000 low-flow aerators on lavatories, over 3,000 low-flow flush valves on urinals and toilets, over 500 low-flow showerheads, and 200 new high efficiency front-loading washing machines throughout campus.
- Duke has replaced all 'once-through' cooling systems in its laboratories with 're-circulating' systems, which reduce consumption by reusing already cooled water.
- Duke has installed hand sanitizers in residential hall bathrooms, kitchens, laundry room and common areas, reducing water demand for washing hands.
- Duke has Modified sterilizers with water saving devices at all Duke University Medical Center facilities.
- Duke has performed an extensive water audit on campus buildings to determine an in-depth awareness of campus water demand distribution. Audit information has been used to identify potential sources of environmental and financial savings.
- For several years, the university has required that all new buildings follow Leadership in Energy and Environment Design (LEED) guidelines, which includes water conservation.

(Roth 2012)(Duke Sustainability 2011)

Conservation Projects—Campus Grounds

- Duke has installed drought-tolerant landscaping throughout its campus, including the use of native species and drought-tolerant turf grasses. In addition, watering of campus trees, shrubs, and gardens has been reduced to twice a week (from three times).

- Duke has reduced the frequency and amount of time that irrigation systems are in operation by 30%. Also reducing water distributed by the university watering truck by 40%.
- Duke has designed a temporary irrigation system that can sustain essential athletic fields. This system involves the use of reclaimed water that is collected and stored in special 10,000 gallon tanks under the bleachers at Soccer and Lacrosse Stadiums.
- Duke also installed cisterns all over campus that are able to collect as much as 150,000 gallons of storm water, water run-off, and building condensate that is reused for athletic field and landscape irrigation.
- Duke has increased the size of irrigation ponds all over its golf course to allow for more natural water storage.
- Duke has implemented a system that collects rainwater that falls on the roof of the Fitzpatrick Center for Interdisciplinary Engineering, Medicine and Applied Sciences. This rainwater is gathered and stored in a hidden 70,000-gallon cistern and used to irrigate the nearly two-acre complex.
- Duke has adopted many soil conservation practices, such as; creating compost from leaves, food waste, and annual flowers; and using recycled woodchips as mulch. These practices help soil to remain healthy and retain water longer.

(Roth 2012)(Dickinson 2005)(Duke Sustainability 2011)

Conservation Projects—Central Infrastructure

- Duke has installed a reverse osmosis system on the cooling tower 'blowdown'. On an average day these towers discharge about 50,000 gallons of wastewater straight in the sanitary sewers. The reverse osmosis system 'reclaims' this water by cleaning it at reusing it back in the cooling towers.
- Duke has installed a system that pipes air handler unit condensate from campus buildings into the same flow as the reclaimed water from the reverse osmosis system to be used on the cooling towers. In addition, a condensate transfer system was installed to move condensate between the East and West steam plants.
- Duke has begun pumping water out of the campus creek, and has drilled 2 wells to further meet cooling tower needs. These actions further reduce their demand upon the municipal water supply by drawing from interior water sources.
- Alternate sources of water; including water from the reclaimed reverse osmosis, the condensate pipes, the creek, and the wells, accounts for over 40 million gallons of water per year—33% of cooling tower needs.
- Duke has made improvement to its steam plants that are estimated to save 12 million gallons of water per year.

(Dickinson 2005)(Duke Sustainability 2011)

Conservation Projects—Educational and Community Outreach

Educational outreach programs include:

- Duke has implemented programs to raise water conservation awareness by strategically placing signs at decision-making points like faucets, showers, water fountains and toilets.

- Duke has initiated an education campaign by handing out flyers that aim to urge students to practice water conservation in dorms—such as limiting shower time and turning off the tap while brushing teeth. Students are also being urged to report leaks.

(Dickinson 2005)(Duke Sustainability 2011)

Community outreach programs include:

- Duke has supplied the University and Medical Center staff, employees, and students with 10,000 free low-flow shower heads for their homes. Each 1.5 gpm showerhead will save an estimated 7,300 gallons of water annually—totaling an estimated savings of 73 million gallons per year).

(Roth 2012)(Dickinson 2005)(Duke Sustainability 2011)

The findings of this project's research into nationwide university conservation efforts concludes that the majority of the water conservation strategies explored in the literature review both can be, and currently are being, implemented in university settings with strong results. Both Stanford and Duke have achieved water-demand reductions of over 200 million gallons per year as a result of the development and execution of their comprehensive water management plans. This indicates the sheer potential for seeing water demand reductions in the university setting, establishes the existence of university water conservation programs, and identifies leading water management plans to be used as model programs as Illinois Wesleyan pursues its own water management plan. However, before IWU develops a plan for future improvements, it is necessary to understand current campus water demand and distribution trends, as well as current water-use practices. Understanding such attributes establishes a solid foundation upon which a future water management can be developed.

Findings: Interviews with Key Informants at Illinois Wesleyan University

The purpose of the third task of my research plan was to: (1) to gather and compile an understanding of water conservation awareness of department heads and key administrators, (2) to determine current or recent efforts to reduce water usage in each department, and (3) to identify current and past water distribution patterns. To achieve these goals, a series of in-depth interviews with key personnel on campus were conducted which revealed both qualitative and quantitative data about current water use, demand, and distribution on campus. Qualitative data, regarding current water-use practices of each department, was retrieved from interviews with Millard Jorgenson, Director of Physical Plant; Mike Welsh, General Manager of Food Services; and Matthew Damschroder, Assistant Dean of Students—Office of Residential Life. Quantitative data, regarding water demand and distribution trends, was also retrieved from the interview with Millard Jorgenson, Director of Physical Plant. Findings from my research are included below:

Qualitative Data

The majority of information acquired was qualitative data regarding current water-use practices of major departments and the school as a whole. According to Millard Jorgenson, water conservation efforts from Illinois Wesleyan University can be summarized by, "doing what we can as we go along" since about 1988 (M. Jorgenson, personal communication, November 5th, 2012). Infrastructure-wise, the school hasn't made any big efforts as water conservation hasn't been a substantial priority. The University doesn't pay much attention because the water bill is still fairly cheap, only comprising about 2-3% of the University's total budget. Furthermore, it was added that a portion of this bill is a result of a fee charged by the local municipalities for campus run-off that enters city sewers. However, this doesn't mean the University just outright refuses when proactive water conservation measures get proposed. Practicality is usually the first question, as in order for the school to seriously consider such measures, the school usually looks for a payback period of less than 5 years (M. Jorgenson, personal communication, November 5th, 2012).

Despite not being a proactive plan to deal with water conservation, the "doing what we can as we go along" strategy implemented by the school has resulted in some conservation efforts. These efforts will be explained and grouped into the following categories: academic buildings, athletic facilities, service buildings, dining facilities, and residence halls.

Academic Buildings

The entire school is individually metered which is major requirement when developing a water management plan that accurately addresses water consumption (Vickers 2001; M. Jorgenson, personal communication, November 5th, 2012). All urinals in academic buildings are retrofitted with auto sensors but not all toilets due to complaints about over-flushing. Upon installing auto sensors on school toilets, Jorgenson began receiving complaints of toilets flushing 2 or more times due to over-sensitivity to movement. In addition, the only non-athletic related irrigation is for the president's lawn and, starting this year, the quad. However, the quad is only being irrigated due to construction of a new classroom building and most likely will not be used once the quad grass has been regrown. Regarding the new building, it and all new construction will comply with all current codes, including water-flow restrictions on all fixtures and appliances (M. Jorgenson, personal communication, November 5th, 2012).

Athletic Facilities

All urinals are retrofitted with auto sensors in the University's athletic facilities. Also, all showerheads are low-flow. Jorgenson conveyed some trouble experienced with the fixtures, where particles of old piping flake off and plug the fixtures up. Furthermore, all irrigation (excluding irrigation mentioned under Academic Buildings section) happens for athletic fields, including the baseball, softball, soccer, and football practice fields. Due to the recent installation of a turf football field, all previous irrigation for the field has been eliminated. The school irrigation system runs on automatic timers, which only run the system during the night. The pool, which was constructed in 1988, uses one of the first water conserving technologies implemented at the school. Most pools being built at the time were using a sand filtration system which uses about 2 million gallons per year. The Fort Natatorium uses a DTE filtration system, which only uses about 2,000 gallons per year. Jorgenson noted that a major leak occurred last year behind Shirk Athletic Center, which resulted in the partial flooding of the east-side parking lot. The school practices proper leak maintenance, fixing leaks right away and encouraging immediate reporting of leaks (M. Jorgenson, personal communication, November 5th, 2012). An interview with the Athletic Equipment Manager was meant to supplement this data; however, due to time constraints the interview never occurred.

Service Buildings

Illinois Wesleyan University uses cooling towers to cool down water that is used for air conditioning in buildings across campus. The cooling towers typically operate between April 15 and October 15. The school runs 5 separate cooling towers, including: 3 main towers, located in Ames Library, Memorial Center, and the Center for Natural Sciences; and 2 smaller towers, located in the Theatre building and Presser Hall. The school's two geothermal systems, one in the Welcome Center and the other in the new classroom building, reduce demand from the cooling towers (M. Jorgenson, personal communication, November 5th, 2012).

Dining Facilities

The Bertholf Commons' (the school's main cafeteria) uses water to clean equipment and dinnerware, and prepare meals. It uses water based on need. Utensil and small equipment is hand-washed in small sinks, the bigger equipment goes to the 'pots and pans' sink where it gets hand-washed as well. The bigger dishes, as well as the majority of the dinnerware, are only run through the main dishwasher during major meals; otherwise the main dishwasher remains offline. In 2010, the entire cafeteria went tray-less, eliminating the amount of water needed to wash trays. However, many students still eat second and third helpings, meaning the amount of dishes has arguably remained consistent (M. Welsh, personal communication, November 5th, 2012).

Residence Halls

Similar to athletic facilities, all urinals have been retrofitted with automatic sensors and all showers are low-flow fixtures. The same problem with clogging of fixtures exists in residence halls. The new student apartments currently under construction will have flush assists and will be completely outfitted with low-flow appliances (M. Jorgenson, personal communication, November 5th, 2012). In addition, all residence hall washing machines have been replaced with high-efficiency, ENERGY STAR awarded washing machines. Residence halls have implemented education and outreach programs in the past including: the posting of stickers, signs, and notices full of water conservation tips and reminders; and peer to peer programs where the residential advisers (RA) of each floor meet and discuss efficient practices (M. Damschroder, personal communication, November 7th, 2012). One idea put forth by Damschroder was the use of residence hall fees as funding for retrofits. Part of each student's housing fees includes a $15 'residence hall' fee which is typically funneled to the hall's elected government to be used throughout the year. Typical uses include: pizza parties, game nights, and other social events; or the purchase of recreational and cooking equipment. Damschroder postulated that with the right 'eco-minded' student government, this money could be used to retrofit existing fixtures, thus combining resource use and awareness for students (M. Damschroder, personal communication, November 7th, 2012).

Quantitative Data

Access to Illinois Wesleyan University's yearly water-utility bills from August of 2006 through July 2012 was obtained during the November 5th interview with Millard Jorgenson. The monthly data was organized by demand location and the sums of each fiscal year (August through June) were expressed. This data showed IWU's annual water demand and costs, distributed amongst campus buildings. IWU's water consumption was the highest during the 2012 fiscal year at approximately 36 million gallons and lowest during the 2007 fiscal year at approximately 14 million gallons (Figure 1). In addition, using the totals in water consumption for each year, totals in dollar amount paid were found. IWU's overall water bill was highest during the 2011 fiscal year at approximately $268,000 and lowest during the 2010 fiscal year at $196,000 (Figure 2).

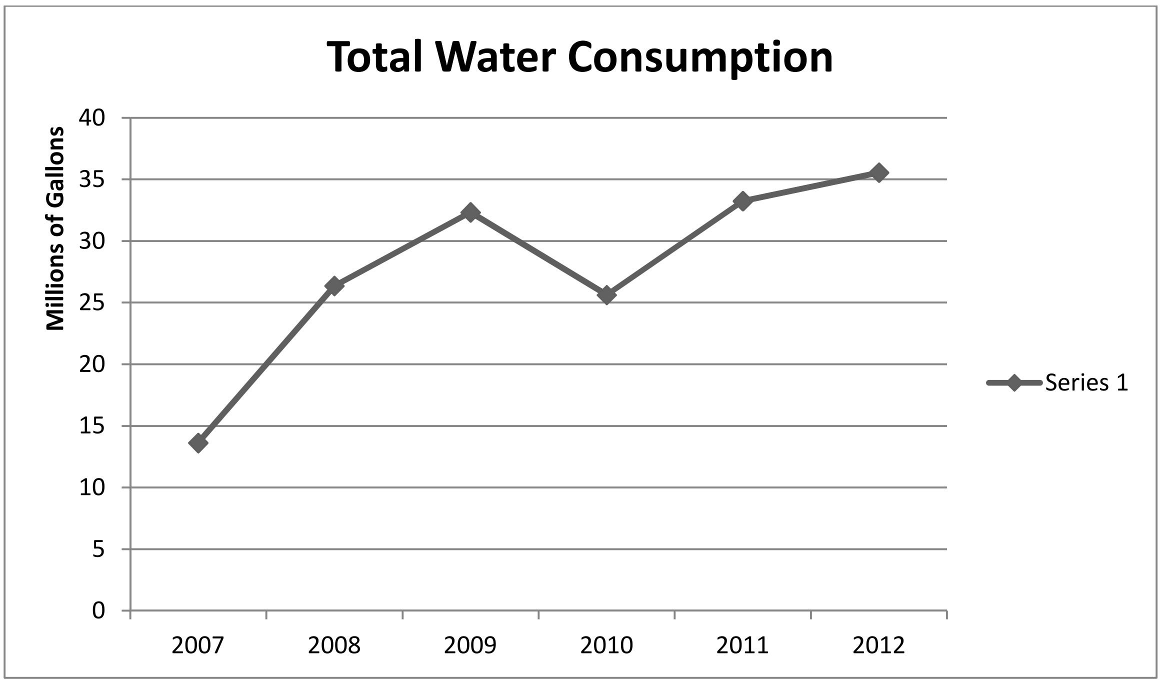

Figure 1. The above figure shows the total annual water use during fiscal years 2007 through 2012. Data used in the creation of this chart was obtained from Illinois Wesleyan University's water utility bill.

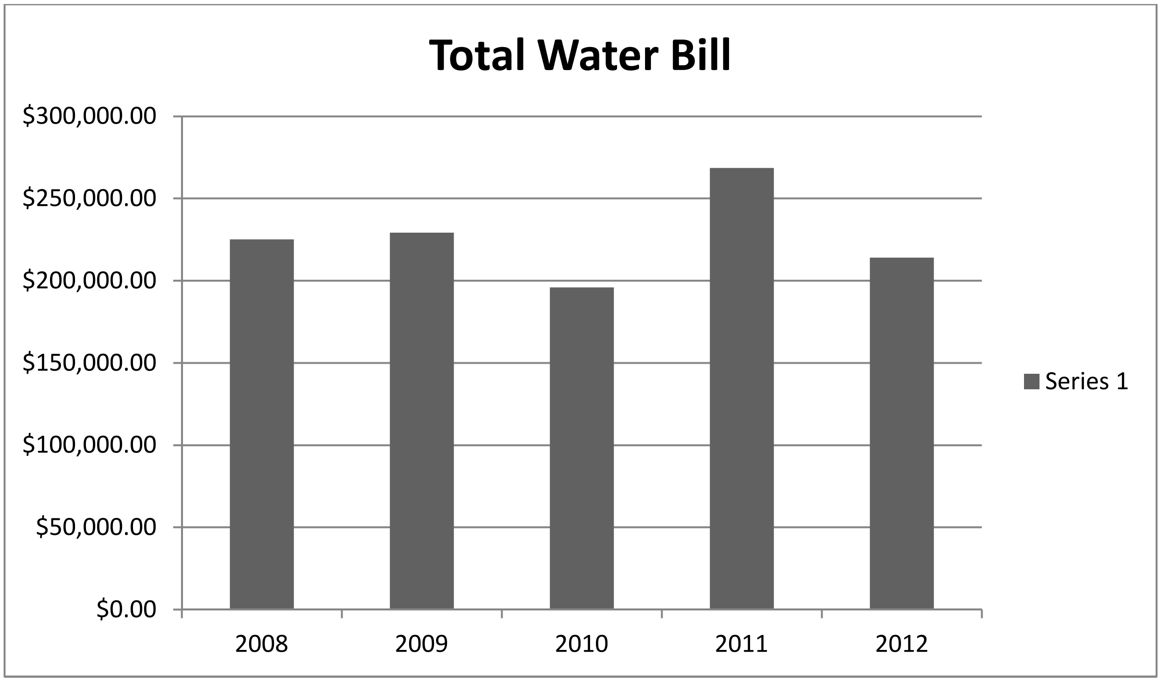

Figure 2. The above figure shows the total annual water bill during fiscal years 2008 through 2012. Data used in the creation of this chart was obtained from Illinois Wesleyan University's water utility bill.

This disparity in total water consumption in reference to overall water bill can be attributed to changes in what IWU paid for each gallon of water from year to year. Using data from Figure 1 and Figure 2, the average annual cost of water was calculated (See Figure 3). The calculated cost of water takes into account the sum of money IWU spends purchasing the water as well as the fee that the University pays for the water to enter the public sewage system. Since the average cost was calculated this way, there may be differences between the values from Figure 3 and the amount which IWU actually spent on the water. However, this cost is more reflective of the value that IWU pays for the lifetime-use of each unit (each unit being 1,000 gallons of water).

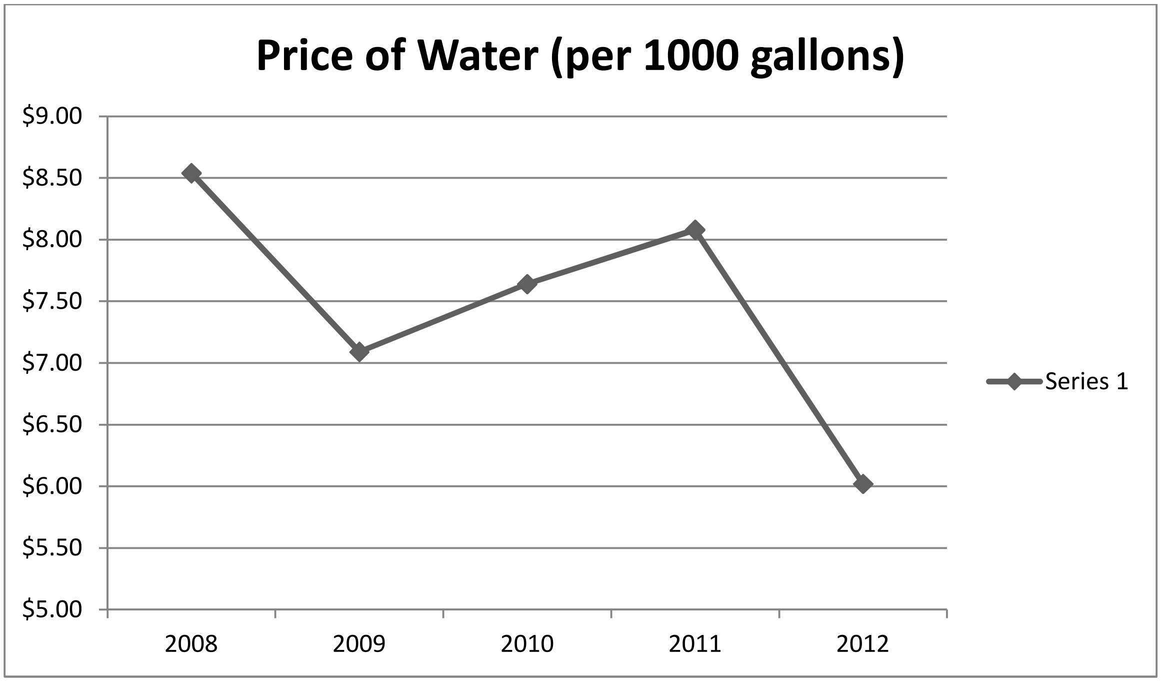

Figure 3. The price of water was calculated by dividing Illinois Wesleyan University's total annual water bill by its total annual water demand (divided by 1,000). Since 2008, the price of 1,000 gallons of water has decreased by $1.50.

The data collected from the utility bills was also used to determine water demand distribution trends on the Illinois Wesleyan Campus (see Figure 4). Unfortunately, there are no sub-meters on some of IWU's buildings and facilities meaning that there are certain cases in which groups of buildings are all measured as one unit. For example, at the time of this data collection, specific data on the University's dining facilities did not exist. Tommy's was seemingly grouped into Hansen, while the Bertholf Commons and the Dugout were incorporated into Memorial Center's meter. For this reason, the category of 'Dining Facilities' used in the 'Qualitative Data' section of findings above has been eliminated and combined with 'Academic Buildings'. To generalize how water is used at Illinois Wesleyan University, buildings were separated into four categories: academic buildings/dining facilities, athletic facilities, service buildings, and residential.

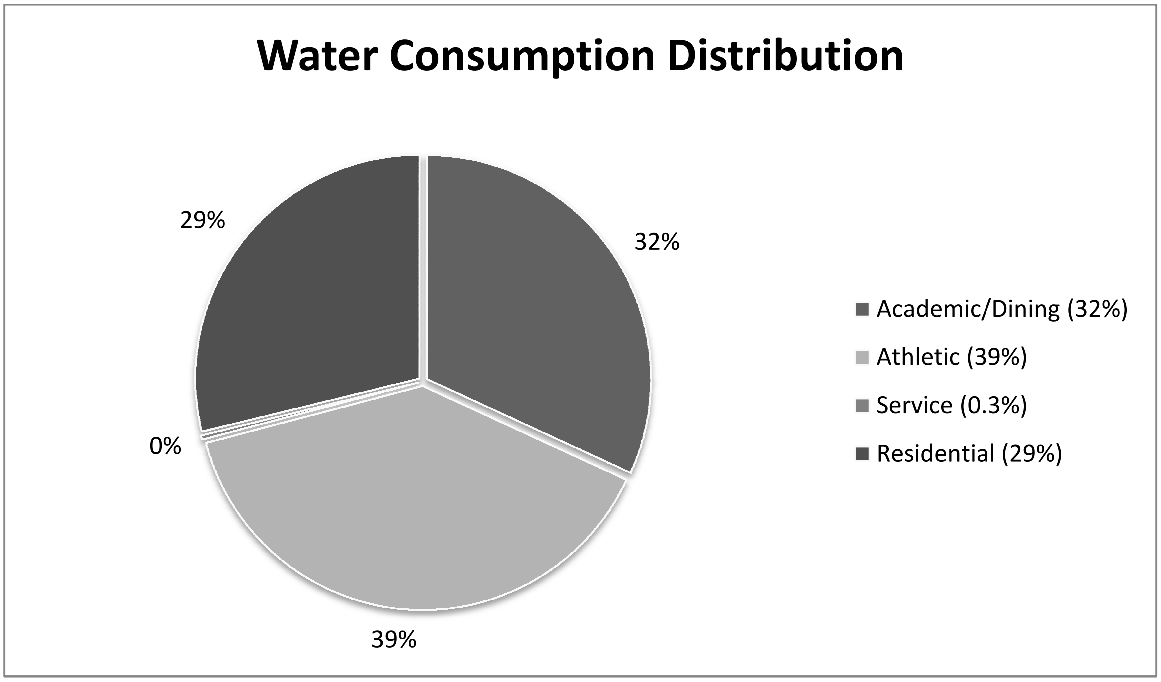

Figure 4. This figure represents the percent breakdown of Illinois Wesleyan University's total water use by various sectors of consumption.

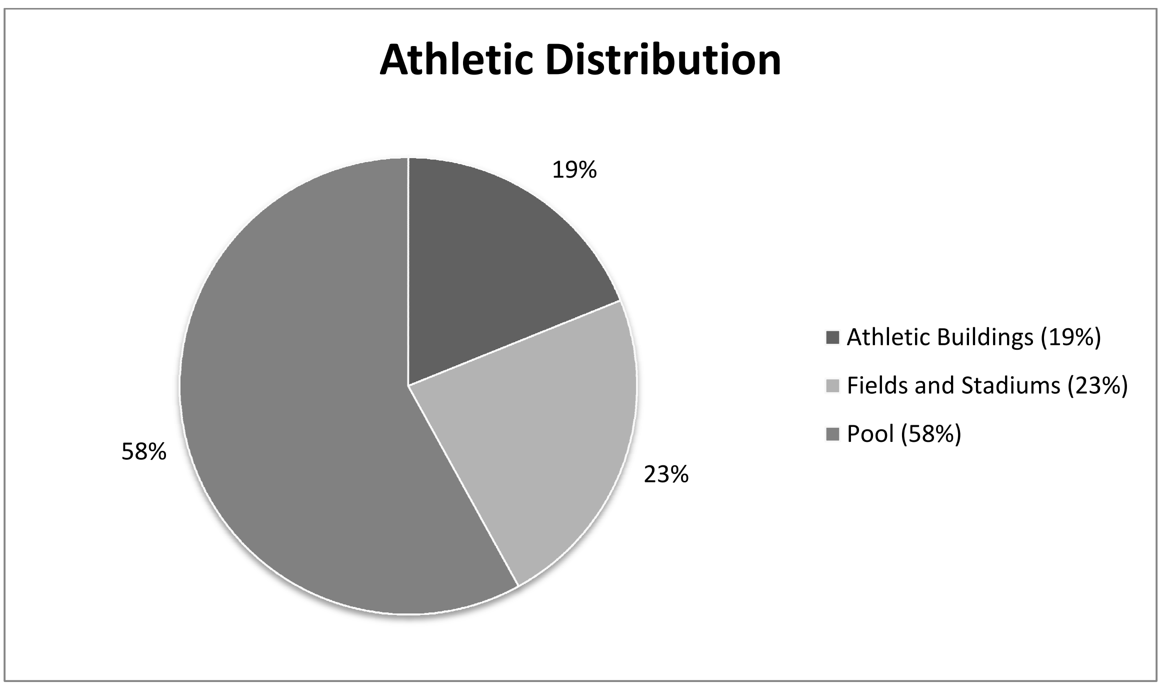

Figure 5. This figure represents a breakdown of how water is used within the athletic sector. Athletic Buildings include Shirk Athletic Center and Athletic Storage. The fields and stadiums that are included in this data are the soccer field, softball field, Francis Field, and the football stadium. The pool is Fort Natatorium.

To further break down each segment, I divided certain slices of the pie from Figure 4 into smaller slices representing water use (see Figure 5 and Figure 6). The same limitations and problems existed at the small scale as the large skill, but the data are still important to recognize.

Athletic Facilities

Illinois Wesleyan's athletic facilities used nearly 14 million gallons of water in the 2012 fiscal year. A little over 8 million gallons of this is used in the Fort Natatorium pool—comprising about 60% of overall athletic use. 23% is used for athletic fields and stadiums. The majority of this portion's use goes to irrigation of turf; however, also included are the bathroom and concession facilities of the stadium. The remaining 19% goes to athletic buildings on camps. The majority of this goes to the Shirk Athletic Center.

Service Buildings

Distribution to service buildings was not significant enough to produce a graph. None of the cooling towers located across campus are separately metered so all cooling tower related water demand was incorporated into the buildings which house each tower.

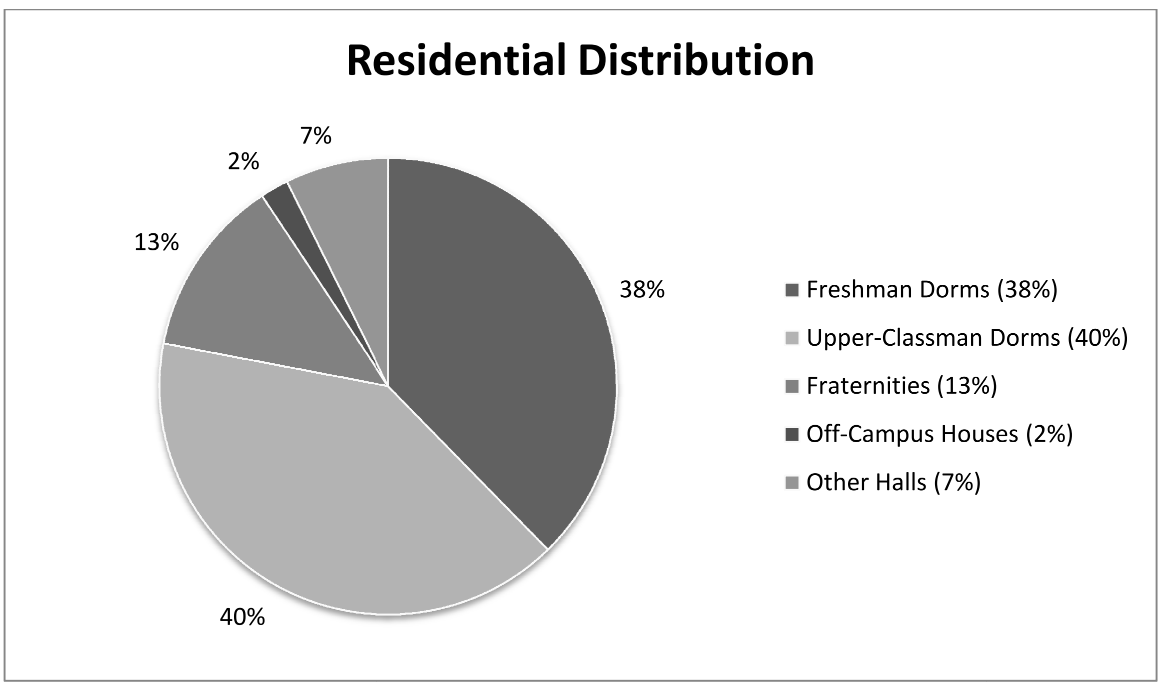

Figure 6. This figure represents a breakdown of how water is used within the residential sector. The freshman dorms portion is composed of Dolan Hall, Munsell-Ferguson Hall, and Gulick Hall. The upper-classman dorms portion is composed of Harriet-Rust House, Pfieffer Hall, Martin Hall, Magill Hall, Kemp Hall, Adams Hall, and Dodds. Fraternities include TKE, FIJI, SIG CHI, and THETA CHI. Off-campus housing and other halls are composed of a miscellaneous assortment of housing options.

Residential Sector

Water use within the residential sector can be examined in Figure 6. Dorms on campus consume the vast majority of residential water demand at almost 80%. Distribution between freshman and upper-classman dorms is pretty uniform, with freshman dorms at 38% and upper-classmen at 40%. Demand sources in these resident halls include uses for sinks, showers, toilets, and washing machines, as well as mop sinks for the janitorial staff.

Findings: City of Bloomington Water Supply and Drought Measures

The purpose of the fourth task of my research was to: (1) better illuminate the water resources available to the City of Bloomington; (2) expose why insecurities about the water supply exist; and (3) understand and dissect water source conservation measures, expected consumption cuts, and restriction levels during the threat of a draught. To achieve this, a process of exploring contacts for the City of Bloomington Water Department led me to a series of documents published on the City of Bloomington's web page. Off the sites 'Drought Preparedness' page, documents consulted included the 2012 October and September Drought Reports, the 2006 "Drought Response Plan", and the city's "Interim Water Supply Plan" that was published in 2010. Analysis of these documents revealed information about the resources from which Bloomington draws its supply as well as the drought measures of the city.

The City of Bloomington relies on two surface water resources for its community potable water supply. The water from Evergreen Lake and Lake Bloomington is distributed locally to consumers in Bloomington, Towanda, Hudson, and the Bloomington Township after receiving treatment at Lake Bloomington Treatment Plant. Together these resources supply for a demand of approximately 11.5 million gallons per day ("Interim Water Supply Plan" 2010). Currently, it is estimated that current water reserves could supply for this demand for up to two years; however, trends in the City's water demand have continued to grow along with the increasing population of the city. Over the past 30 years, the average daily demand has increased by 4.4 million gallons per day; and during peak seasons, this demand has reached staggering levels. Peak demand of the city has reached as high as 21.6 million gallons per day—almost twice the current average of 11.5 million gallons per day ("Interim Water Supply Plan" 2010). As population continues to grow, someday this peak demand may be unquenchable by the city's supply, especially if the supply remains as fragile as it is.

Sharing a border with Bloomington lies the city of Normal, which draws its water from a completely separate resource: a massive groundwater reservoir known as the Mahomet Aquifer. Together they provide potable water to the twin cities' 125,000 citizens ("Student Life"). Normal's massive groundwater supply has proven to be superior to Bloomington's surface resources in the sense that: it is a much less threatened supply. According to the report, "Public water-supply systems that rely on surface water as their sole source of supply need to have storage far beyond their average needs in order to be resilient to prolonged drought" ("Interim Water Supply Plan" 2010) .The vulnerability of surface water reservoirs in central Illinois has become evident by regional droughts that occurred in 1988 and again in 2005. Concerns about the City of Bloomington's water supply have arisen again due to the recent drought of summer 2012, in which, "the combined level of Lake Bloomington and Evergreen Lake approached 7 1/2 feet below normal, just inches from the 8-foot deficit that will trigger the city's first wave of water-use restrictions" (Wells 2012). The drought months have since passed; only inducing water restrictions categorized as "voluntary" while an active threat. However, the city says that if population and demand continue to increase and another drought hits, "the Bloomington water supply will likely be stressed and water quality problems may become more prevalent" ("Interim Water Supply Plan" 2010).

For this reason the City of Bloomington developed a Drought Response Plan in 2006. The purpose of the Drought Response Plan is to protect the water quality and water quantity of the City of Bloomington, Illinois' water supply during drought and/or periods of water shortage ("Drought Response Plan" 2006). This plan establishes what defines a drought as well as conditions which trigger the different levels of drought status. These statuses are as follows: normal (non drought), moderate drought, severe drought, and extreme drought. The implications of each category with associated responses are discussed in the following sections:

Non Drought

Demand Reduction Expectations: **None**

Normal or non-drought conditions can best be describes as just the average fluctuations in lake levels due to precipitation and extraction rates. Lake levels can drop as low as 6 feet and still be considered normal conditions. The only impacts of these drops are on aesthetic and recreational uses of the supply, so no response plan is necessary ("Drought Response Plan" 2006).

Moderate Drought

Demand Reduction Expectations: **Voluntary 5%**

When a drop in lake level exceeds 6 feet, the City of Bloomington of Bloomington, Illinois Water Department declares a moderate drought and enacts it moderate drought response plan. This response plan simply aims to educate the public and spread awareness about the drought. Restrictions are voluntary, but the hope is to achieve a 5% reduction of demand. Examples of voluntary restrictions include restricting water-use for irrigation and recreational 'water-based activities' such as pools. Also the city ups the use of its leak detection program ("Drought Response Plan" 2006).

Severe Drought

Demand Reduction Expectations: **Mandatory 10%**

Mandatory restrictions don't apply until the city falls into the severe drought category. To reach this category, lake levels must drop below 8 feet. To ensure the sustainability of the water supply during these times, a mandatory restriction of a 10% reduction in demand is set on Bloomington. Under severe drought conditions, many water-uses are prohibited including: sprinklers, other remote broadcast devices, water runoff in landscape maintenance, recreational water use, and irrigation is restricted to two days a week. In addition the city conducts a 24 hour monitoring program in which city employees distribute courtesy warnings to those not following the restrictions ("Drought Response Plan" 2006).

Extreme Drought
Demand Reduction Expectations: **Mandatory 15%**

Once lake levels drop below 10 feet, extreme drought measures are enacted. The overall reduction in demand is raise to 15% as the preservation of the water supply becomes critical. At this stage; residential, commercial, industrial, and institutional customers are required to: "1) reduce domestic water use to minimum levels necessary to maintain health and safety 2) prohibit water-based recreational activities except facilities, such as swimming pools and other related water activities, that employ filtration and/or water recycling 3) use low-volume hand-held applications only and prohibit sprinklers, other remote broadcast devices, and water runoff in landscape design maintenance and 4) restrict landscape watering on Tuesday and Saturday for odd-numbered addresses, and Thursday and Sunday for even-numbered addresses" ("Drought Response Plan" 2006).

Establishing expectations of the city during times of drought is imperative to creating a sustainable water management plan on campus. This task provided an important piece of knowledge that can be used as guidelines as Illinois Wesleyan develops its water management plan. In addition, the restrictions set by the City of Bloomington. Illinois Water Department can be seen as a solid starting point in developing the goals of Illinois Wesleyans water management plan. Using all the information acquired, the final task of this project was to development recommendations as IWU moves in pursuit of a comprehensive water management plan.

Recommendations

A much more comprehensive study of Illinois Wesleyan University's water-use trends must be conducted before solid recommendations can be made. For this reason, recommendations from this project were kept basic and primarily based upon the findings from the literature review and the study of model universities.

Below is a list of major recommendations based upon the research of this project.

1. To continue to better understand our water-use, I recommend conducting a comprehensive and professional water audit for the school. In addition, I recommend that a meter be installed on all buildings currently without; and buildings with multiple uses such as Memorial Center of Hansen be individually metered so the contained dining facilities can be monitored.
2. To reduce indoor water-use, I recommend for the University to continue retrofitting existing plumbing fixtures across all campus buildings including: academic, athletic, service, dining, and residential facilities.
3. To reduce outdoor water-use, I recommend for the University to upgrade existing irrigation systems to either include either WSICS or evapo-transpiration technology. In addition, despite the initial investment, I recommend the school look into the feasibility of implementing rainwater harvesting or greywater reuse systems into existing

infrastructure. Furthermore, Illinois Wesleyan should assess landscape design and continues conversion to more water-wise landscaping as seen in the review of literature.

4. All future construction should include the highest efficiency plumbing fixtures on the market. In addition, new construction serves as the perfect opportunity to include a greywater reuse system in the plumbing.
5. Further research should be conducted into the behavioral change aspect of water conservation.

Limitations

This project acknowledges that this is not a fully developed water management plan for Illinois Wesleyan. The purpose of this project was to develop a resource that the University could use as a reference when developing the actual plan. For this reason, there is still a substantial amount of data to be collected to create a comprehensive guide to an efficient water management plan. Partial data collection is due to several inhibiting factors. For one, there is limited water usage data for certain buildings on campus because the current metering system does not monitor them. In addition, water bills were organized yearly which eliminated the option of developing seasonal water demand data that is necessary to fully understand peak demand of the University. Another inhibiting factor is the time frame of the study. Fully understanding water conservation for an institution the size of Illinois Wesleyan has many facets and requires numerous processes. As a student in the given time frame of a semester, undertaking each and every one of these tasks was simply not possible. Thus, in completing this research, I focused this project primarily on creating a diverse collection of data that lays a solid foundation for further research.

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Conclusion

Water is a vital aspect of our lives; and as long as the rate of demand rapidly increases, the world's freshwater supply will become increasingly threatened. In the upcoming decades, maintaining a sustainable freshwater supply will be an issue pushed to the forefront, requiring a careful reevaluation of how we use it. The best strategy for decreasing overall demand and increasing water-use efficiency in an institutional setting is to develop a comprehensive water management plan. The first step is developing a thorough knowledge of water conservation strategies to implement with in a plan. Furthermore, looking to model university water management plans, such as ones executed at Stanford and Duke, illuminates the indisputable and far-reaching potential for water-demand reductions in the campus setting. In addition, the awareness of such cases offers examples for budding water management plans to emulate. Research into existing water demand trends and current water conservation strategies on the Illinois Wesleyan campus confirms the solid potential for demand reductions. Using all the information acquired, the foundation has been set to begin developing a comprehensive water management plan that will achieve aforementioned demand reduction potential. Consideration of these initial recommendations begins the process of championing Illinois Wesleyan University into the ranks of elite water conserving institutions around the world.

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